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CONSTITUTION*

ARTICLE I

The name of this Association shall be the American Society for Horticultural Science.

ARTICLE II

The object of the Society shall be to promote the Science of Horticulture.

ARTICLE III

Voting members: Any person who has a baccalaureate degree and holds an official position in any agricultural college, experiment station, or federal or state department of agriculture in the United States or Canada, is eligible to membership. Other applicants may be admitted by vote of the executive committee.

Associate Members: Any person not eligible to voting membership will be eligible to associate membership upon vote of the executive committee. Associate members shall not vote and will present papers only at the request of the program committee.

ARTICLE IV

Meetings shall be held annually at such time and place as may be designated by the Executive Committee, unless otherwise ordered by the Society.

ARTICLE V

The officers shall consist of a President, a Vice-President, a Secretary-Treasurer, and sectional chairmen to represent the subject-matter sections of the Society.

ARTICLE VI

The Constitution may be amended by a two-thirds vote of the Society at any regular meeting, notice of such amendment having been read at the last regular meeting.

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*As revised and adopted at the Boston meeting, December 29, 1946.

BY-LAWS

Section 1—*Duties of Officers:* The President shall preside at business meetings and general sessions of the society, deliver an address at the regular annual meeting, and serve *ex officio* as a member of the executive committee.

The Vice-President shall preside at business meetings and general sessions of the Society in the absence of the President and serve *ex officio* as a member of the executive committee.

The Sectional Chairmen shall preside at sectional meetings and serve *ex officio* as members of the executive committee.

The Secretary-Treasurer shall keep the records of the Society; mail to members a call for papers for the annual meeting at least 30 days prior to closing date for acceptance of papers, and at least 3 months prior to the annual meeting shall request of members suggestions regarding nominations, matters of policy and general welfare of the Society; serve *ex officio* as a member of the executive and program committees; collect dues from members; and conduct the financial affairs of the Society with the aid and advice of the chairman of the executive committee.

Section 2—*Executive Committee:* There shall be an executive committee consisting of the retiring President, who shall be chairman, the President, the Vice-President, the Sectional Chairmen, the chairmen of regional groups, the Secretary-Treasurer, the Editor-Business Manager, and two members elected at large for terms of two years each, retiring in alternate years. This committee shall act for the Society in the interim between annual meetings; shall fix the date for the annual meeting; shall present at each annual meeting nominees for members of the nominating committee; shall act on admission of all associate members, regional groups and junior branches and in special cases may elect to voting membership persons of high qualifications but otherwise ineligible; shall consider matters of general policy or welfare of the organization and present its recommendations at the annual meeting of the Society.

Section 3—*Nominating Committee:* There shall be a committee on nominations consisting of two members from each of the sectional groups who shall be nominated by the executive committee and elected by ballot at each annual meeting of the Society. It shall be the duty of this committee, at the following annual meeting to present a list of nominees for the various offices, committees (except the Nomination Committee), representatives, and sectional chairmen who shall be selected after consultation with the sections. This committee shall also nominate referees and alternates upon special subjects of investigation or instruction which may be referred to it for consideration by the Society. The duties of these referees shall be to make concise reports upon recent investigations or methods of teaching in the subjects assigned to them and to report the present status of the same.

Section 4—*Program Committee:* There shall be a committee on program consisting of five (5) members, including the Secretary and the Editor. This committee shall have charge of the scientific activities of the Society, except as otherwise ordered by the Society. It shall receive titles and arrange the program of the annual meeting; arrange symposia; accept or reject titles, and may invite non-members to participate.

Section 5—*Editorial Committee:* There shall be an Editorial Committee consisting of five members. One member shall be elected each year to serve for five years. It shall be the duty of this committee to formulate the editorial and publication policies of the Society; to assist the Editor in reviewing and editing papers and shall have final authority to reject any paper deemed not worthy or unsuitable for publication in the PROCEEDINGS. The Committee at the call of the senior member shall elect a chairman from among its members, who shall serve for the calendar year.

The Committee shall appoint an Editor and Business Manager of the PROCEEDINGS, subject to the approval of the Executive Committee. He shall serve for a period of 3 calendar years, and shall be charged with editing, publishing and

distributing the PROCEEDINGS. He shall serve *ex officio* as a member of the Executive Committee.

Section 6—*Membership Committee:* There shall be a committee on membership whose duties shall be the promotion of membership in the Society.

Section 7—*Auditing Committee:* There shall be a committee to audit the books of the Society and report their condition at each annual meeting.

Section 8—*Committee on Local Arrangements:* There shall be a committee on local arrangements who in cooperation with the Secretary-Treasurer will have charge of all local arrangements for the annual meeting.

Section 9—*Quorum:* Ten members of the Society shall constitute a quorum for the transaction of business at a regularly called meeting of which at least 30 days notice shall have been given to members.

Section 10—*Annual Dues:* The annual dues of the Society shall be six dollars.

Section 11—*Amendment to the By-Laws:* The by-laws may be amended at any regular meeting by a two-thirds vote of members present providing a copy of such amendment has been sent to all members at least 30 days prior to the meeting.

Section 12—*Regional Groups:* Upon the presentation of a petition signed by ten or more members of this Society residing within a stated region, the executive committee may approve the formation of a regional group affiliated with this Society. Such group must elect as a minimum number of officers as chairman, a vice-chairman and a secretary and shall present an annual report to the Secretary-Treasurer of the national Society to include the names of its officials and a review of its meetings or other activities. Publication of this report in full or in part shall be made in the PROCEEDINGS of this Society. Papers presented at regional group meetings may be published on the same basis as papers presented at the regular annual meeting.

Section 13—*Junior Branches:* A student horticultural group at a college or university, operating under the supervision of a member or members of this Society, may organize as a Junior Branch of the American Society for Horticultural Science upon approval of the executive committee and the payment of an annual fee of six dollars for the branch. Each branch shall receive a copy of all publications of the Society. Such a branch shall elect a chairman, a vice-chairman and a secretary-treasurer and shall present an annual report of its activities to the national Secretary-Treasurer. Such groups may hold meetings in conjunction with the annual meetings of this Society and a report of such meetings, not including individual papers, may be included in the PROCEEDINGS.

Section 14—*Term of service for elected officers:* The term of service for elected officers shall be from the close of the annual meeting at which they are elected until the close of the next annual meeting.

The Variation in Individual Valencia Oranges from Different Locations of the Tree as a Guide to Sampling Methods and Spot-Picking for Quality
I. Soluble Solids in the Juice

By JOHN W. SITES and HERMAN J. REITZ, *Citrus Experiment Station, Lake Alfred, Fla.*

THIS research was originally undertaken with three objectives in mind:

First, to obtain information which could be used as a guide for accurately sampling small plots of trees, using a minimum number of fruit per sample.

Second, to aid in outlining a simple procedure for sampling large blocks of trees which could be used by commercial packing house personnel. In Florida and other citrus areas, shipment of citrus to market is possible only if the fruit meets state-enforced "maturity standards". It is the responsibility of the packer to deliver fruit to the packinghouse which meets the minimum maturity standards. A simple and reasonably accurate procedure for sampling large blocks of trees minimizes the packers risk.

Third, to secure data on variation of fruit on individual trees so that a more accurate job of spot-picking for internal quality can be done by commercial pickers. In the past spot-picking has been done largely to obtain desired sizes with little attention given to location of fruit on the tree. A limited amount of spot-picking, practiced during the past few years, has been confined chiefly to grapefruit, with little or no spot-picking of oranges. A number of proposals have been made to raise the minimum maturity standards and to establish grades based on the quantity of the juice. Adoption of such regulations will create the problem of distinguishing the high quality fruit on the tree. Grove-run early oranges, especially Hamlin and to some extent Parson Brown varieties, will not always meet the present minimum standards for percentage soluble solids early in the season, and if higher standards are adopted spot-picking will have to be used. An understanding of the variation which occurs among fruits on the same tree is essential to the solution of these problems.

Data compiled as a result of this study are of further value for testing the practicalness of using individual fruit rather than composite samples for checking compliance with maturity and internal grade standards.

Five different components of the juice were studied: (a) per cent citric acid, (b) per cent soluble solids, (c) vitamin C, (d) per cent of juice by weight, and (e) volume of juice per fruit. At the time the fruit was removed from the tree each fruit was catalogued as to size, amount of shade and light it received, color, type of injury, if any, and direction of exposure, so that the correlation between these factors and the constituents in the juice could be determined. Approximately 1,800 fruits were removed from the tree and so classified.

In 1943 preliminary work of a similar nature was done with Va-

lencia oranges and Duncan grapefruit, that experiment being less detailed but involving 18 trees (5). That experiment was largely exploratory, and was designed to determine whether large differences in fruit composition could be found which were related to position of the fruit on the tree. Results showed in general that the soluble solids and vitamin C content were higher in fruit taken from the outside of the tree than from fruit taken from the inside, with no significant differences in titratable acid being found. Winston's work, also done in Florida, shows similar trends (7). The work of Sites *et al* (5) further showed that fruits from the upper portions of the tree and fruits from the south and west sides of the tree were higher in soluble solids, vitamin C and titratable acid than fruits from the lower part of the tree or from the north and east sides. Wood, working in Texas, reported similar differences in Marsh grapefruit as affected by position of the fruit on the tree (8). Recently Randhawa and Dinsa (4) reported work done in India similar to that done in 1943 at this Station, but they found no significant differences in acid or soluble solids content as affected by exposure, appearance or height.

These results served as a background for this study.

Materials and Methods

In March, 1948 a Valencia orange tree which was considered representative of the variety and was bearing an average crop of fruit was selected at the Florida Citrus Experiment Station for use in this study. The selected tree, budded on rough lemon root-stock, was approximately 28 years old and in good physical condition. The circular area under the tree was laid off into approximately 19 degree sectors which were plainly marked with large stakes. Thus the area was marked off into 19 separate sectors, radiating outward, with the trunk of the tree as the focal point (Fig. 2). The sector in which the fruit was located was then recorded as the fruit was removed from the tree. Each of the main branches was numbered and tagged and the branch number was recorded for each fruit as it was removed. The exact position of each fruit on the tree within 6 inches was determined by the use of long calibrated poles. The distance from the ground to the fruit, the distance from the trunk of the tree to the fruit, and the distance from the trunk to the periphery of the tree was recorded for each fruit as it was removed.

At the same time each fruit was also classified as to its position in relation to shading by the leaf canopy. These classifications included "outside-fruit", which was fruit on the outer fringe of the leaf canopy which would receive maximum light available in any specific sector of the tree. "Canopy-fruit", was classified as fruit embedded in the canopy of the tree. These fruits were at least partially shaded at all times. "Inside-fruit", was that fruit which hung inside the main body of the leaf canopy, relatively close to the trunk, with few leaves between it and the trunk. In general, this fruit was in continuous full shade at all times. "Top-outside-fruit" included all fruit in the top of the tree which was on the outside of the canopy. This fruit received full light and was not affected by the direction of light. "Top-inside-

fruit" was classified as fruit which was in the top of the tree but was embedded in the foliage so that it received direct light only intermittently. The canopy was thinner in the top than on the sides of the tree and this fruit received more light than that which was classified as inside-fruit.

It will be apparent from these descriptions that the basic characteristic used to classify a fruit was the amount of light or of shading to which it was subjected. In the remainder of this paper, these classifications will be referred to by the general term of "light classes". It is not inferred by this usage that the differences shown below are due solely to the differences in light which impinged upon the fruit and the immediately surrounding leaves. There can be little doubt that strong correlation exists between the light factor and the level of soluble solids in the juice of the individual oranges, but this does not imply a causal relationship between them. No explanation of the results is in reality possible, since there is no reason to believe that the intensity of vapor pressure gradients, temperature, osmotic concentrations in the leaves, or relative amounts of the ash elements in the leaves was constant throughout the canopy of foliage. In the absence of data to the contrary, it is possible that these factors are more responsible for the differences to be shown below than are the light factors. However, since the classification of the fruit was based upon the amount of light or shade to which it was subjected, the results are presented on that basis, with no attempt being made to explain the results but only to point them out and to apply them to the practical problem of spot-picking and sampling.

These classifications were of course made at the time of maturity of the fruit. Had they been made at the time the fruit was very small in size, no doubt many of them would have fallen into a different class due to the sagging and bending of the branches as the fruits increased in weight.

As each fruit was removed from the tree it was given a number which was written on the side of the fruit with a special fruit-marking pencil. All data pertinent to this fruit were then recorded opposite the number. After being removed from the tree the fruit was placed in field boxes and taken to a 40 degree F storage room. Fruit was removed to storage within a maximum of 3 to 3½ hours after it was removed from the tree. The operations were set up with two crews, one in the field removing the fruit from the tree, the other in the laboratory running analyses on the fruit at the same time. This was done in order to remove all the fruit from the tree as nearly at one time as possible and also to reduce to a minimum the length of time which the fruit would have to stay in storage after being removed from the tree. All fruit was removed from the tree after 6 days and the analyses were completed in 15 days. In the laboratory the diameter, weight and commercial U. S. grade of each fruit was recorded. The color of the rind was determined by placing each fruit in a machine which spun the fruit rapidly, resulting in a uniform color which was matched against standard color plates for oranges and grapefruit as used by Harding *et al* (1, 2). In addition each fruit was examined and classi-

fied as to type of injury or rind blemish, whether the cause was insect, disease or mechanical.

The following brief descriptions are given of the methods used in preparation and analysis of the juice:

Extraction:—The fruit was cut in half and the juice extracted by a small metal hand press. Samples were put through a straining device to remove large fragments of albedo and other large solid particles.

Weight of Juice:—Weight of extracted juice was measured in grams.

Volume of Juice:—Volume of juice was measured in milliliters.

Per Cent Citric Acid:—The citric acid content (considered as total titratable acidity) was determined by the titration of a 25 ml aliquot of clear juice against .3125 N sodium hydroxide solution and calculated as per cent anhydrous citric acid by weight.

Per Cent Soluble Solids:—Soluble solids were measured by the use of a Bausch and Lomb, Abbe type refractometer with temperature bath at 28°C. This instrument is equipped with a Brix scale for direct reading.

Vitamin C (Ascorbic Acid):—Vitamin C was determined by titration with a solution of sodium 2–6 dichlorobenzenone-indophenol dye standardized against pure ascorbic acid solution according to the method described by Menaker, M. H. and N. B. Guerrant (3), and reported as milligrams of ascorbic acid per 100 milliliters of juice.

The "Ratio" (soluble solids/titratable acid) and the "Per Cent of Juice by Weight" are calculated values.

The methods used for statistical analyses are those described by Snedecor (6).

Results

Light Classes:—The averages per cent soluble solids of all fruit in these classes together with pertinent information resulting from statistical analysis of the data are presented in Table I. Analysis of variance showed highly significant differences between light classes.

The regression lines in Fig. 1 show the spread in per cent soluble solids between light classes as related to changes in height of the fruit on the tree for each light class. The center of the lines as drawn show the mean percentage soluble solids for each light class and the length of each line represents the mean ± standard deviation of the solids values. Regression equations and "t" values for these lines are presented in Table I.

Fig. 2 shows the average percentage soluble solids values of all fruit in each sector in each light class. These values show the differences in per cent soluble solids which were found among the light classes as affected by direction of exposure to light.

Height of the Fruit on the Tree:—The percentage soluble solids in the fruit increased with increase in height of fruit for all the five light

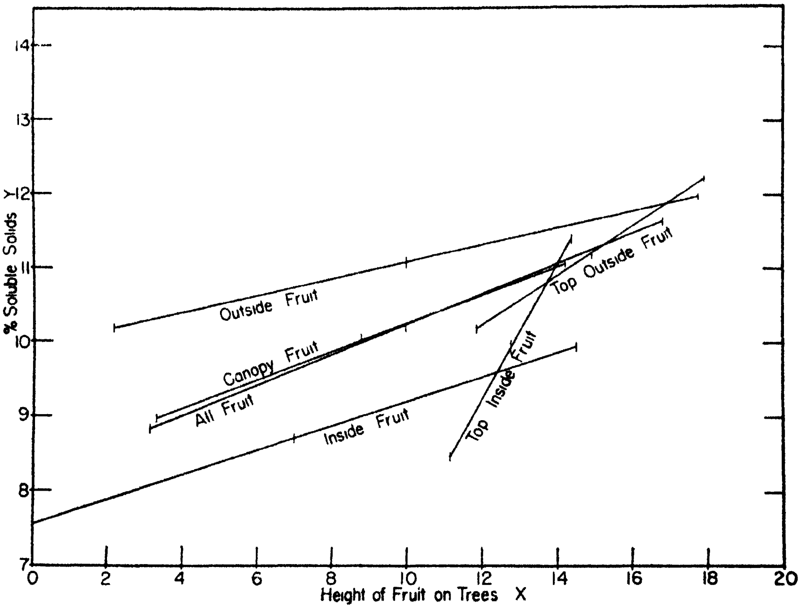

FIG. 1. Regression of per cent soluble solids on height of fruit for all light classes (see Table I for regression equations and "t" values).

classes, as shown in Fig. 1, and the regression equations of Table I. The effect of height on percentage soluble solids is also shown in Table I by comparing the top-outside and the top-inside fruit with that in the other light classes.

Direction of Exposure:—The average percentage soluble solids content of the fruit was found to vary with direction of exposure to light. Analysis of variance showed highly significant differences in percentage soluble solids among sectors with lower values found in sectors in the northeast portion of the tree (Fig. 2).

TABLE I—CHARACTERISTICS OF THE DISTRIBUTION OF PER CENT SOLUBLE SOLIDS VALUES OF FRUIT IN FIVE LIGHT CLASSES

Light Classes	No. Fruit	Per Cent of Total Fruit	Ave Per Cent Soluble Solids	Standard Deviation	Maximum Per Cent Soluble Solids Individual Fruits	Minimum Per Cent Soluble Solids Individual Fruits	Regression Soluble Solids on Height*	Value of "t" for Regression Coefficient
Outside	500	28 0	11 08	0 91	13.40	8.40	E = .1173X + 9.915	9.033**
Canopy	580	32.4	10.01	1.05	12.50	5.90	E = .1933X + 8.311	22.06**
Inside	321	18.0	8 70	1.26	11.75	6 00	E = .1655X + 7.545	9.566**
Top—outside	250	14.0	11.21	1.02	13 50	9.50	E = .3337X + 6.227	5.997**
Top—inside	137	7.6	9.93	1.49	12.00	8 50	E = .9199X + 1.827	28.811**
All fruits	1,788	100.00	10.24	1.41	13.50	5.90	E = .2101X + 8.146	30.72**

*E = Estimated value of per cent soluble solids.
X = Height of fruit.
**Highly significant "t" value.

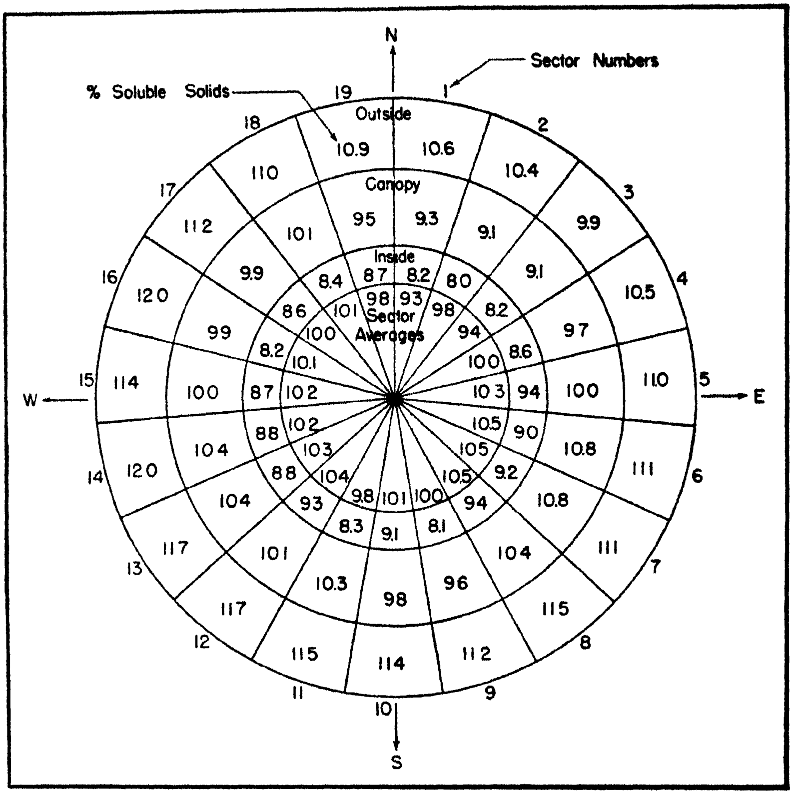

Fig. 2. Effect of direction of exposure and amount of shading on per cent soluble solids content of Valencia oranges.

Rind Color of the Fruit:—Both the color of the rind and the percentage of soluble solids are shown to be very closely related to the amount of light to which the fruit and leaves were exposed. The rind color was originally classified into 21 groups varying from dark green to orange. In preparing Figs. 3 and 4 these classifications were grouped into three large classes: green, yellow and orange. The level of per cent soluble solids of the juice as related to each color class is shown in Fig. 3; and Fig. 4 shows the per cent of oranges in each color class as related to each light class. Weather conditions during the 1947–48 season were not favorable for development of high rind color.

Discussion

It is evident from the results that light is either the principal factor affecting the content of soluble solids in the juice or highly correlated with the factors responsible. The three general classifications presented, light and shade factors, height factors, and direction of exposure to light are all related to the intensity and duration of light. They are

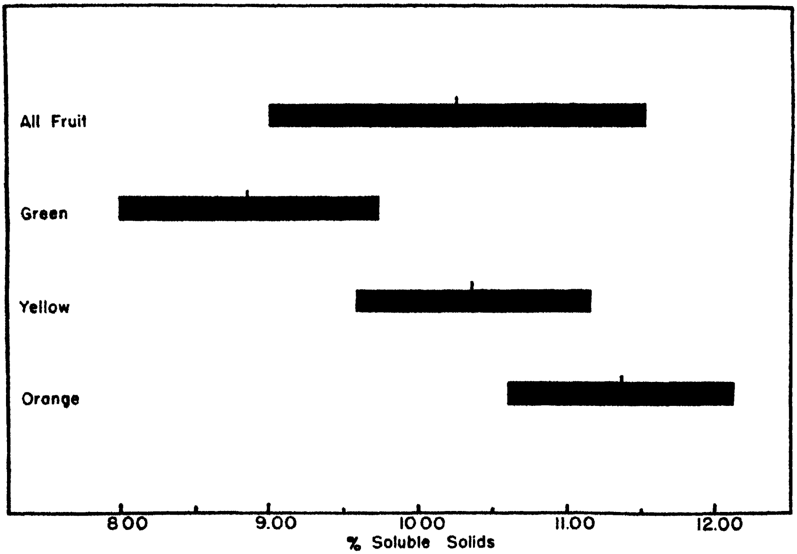

FIG. 3. Per cent soluble solids levels for major rind color classifications. The length of the bars equals the mean ± standard deviation and the point on the bar indicates the mean value.

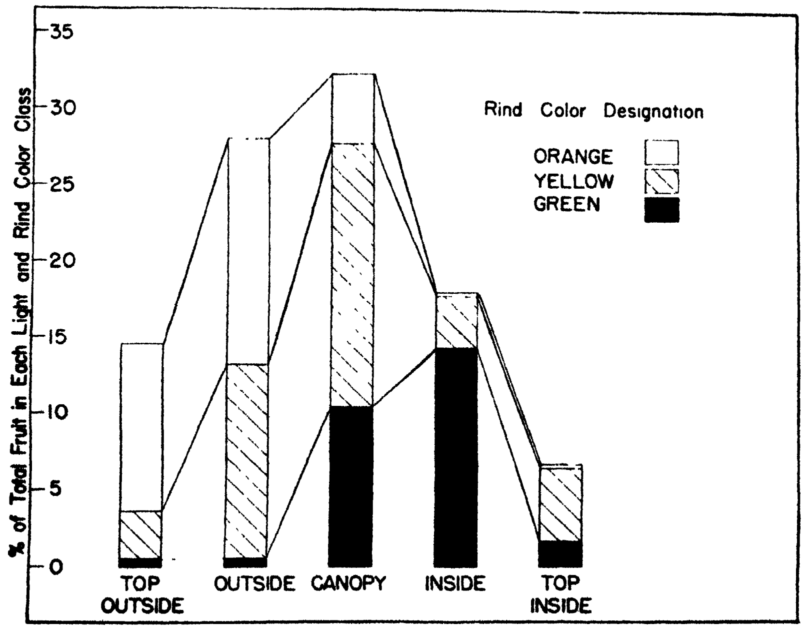

FIG. 4. Color of the rind of Valencia oranges affected by the amount of shading. The length of the bar indicates the percentage of total fruit represented in each light class.

arbitrary classifications used to identify the portions of the tree in such a way that the research worker or the commercial citrus grower can easily locate them.

The regression lines presented in Fig. 1 illustrate three points useful in developing a sampling procedure. The regression line for canopy-fruit almost coincides with the regression line for all-fruit. This group of approximately one-third of the fruit closely represents an average of all of the fruit on the tree in percentage soluble solids. Where large samples are needed for research work, collecting only canopy fruit should provide a representative sample. However, in most cases a much smaller number of fruit is desirable either for research or commercial sampling. The regression lines in Fig. 1 show that fruit taken from the canopy at a height of about 10 feet would have yielded a sample representative of the entire group, or that fruit from the outside of the tree at a height of 3 feet would have yielded a representative sample. Because of the convenience of reaching fruit 3 feet high, the latter point is preferable. Collecting fruit at each of the cardinal compass points eliminates the variation caused by direction of exposure. In other studies the authors have found that large citrus fruits of the same age, variety, and from the same position on the tree contain lower soluble solids than small ones. Therefore all fruits sampled for any given comparison must be of the same size. Thus for sampling small plots, fruit of uniform size, collected from each of the cardinal compass points at a height as close to three feet from the ground as is practical and taken from outside fruit only should give a sample representative of the whole group of fruit on the tree.

The standard deviation from the regression line for all outside fruit was found to be 0.84 per cent soluble solids. Assuming that a difference of 0.5 was desired to represent a significant difference between means at the 1 per cent level, 20 fruits would need to be taken from one tree, or from the trees in each plot. Tree to tree variation would tend to increase this value, while selection of fruit of uniform size would tend to decrease it. Extensive tests at the Citrus Experiment Station indicate that a standard deviation of 0.5 or less in the percentage soluble solids may be expected to result from using this method of sampling plots of trees in a uniform block.

This sampling procedure has been in use at the Citrus Experiment Station since 1944. The reliability of the results for comparing plots may be further increased by sampling at intervals through the season.

For sampling large blocks of trees the procedure may be modified to give more weight to the variation between trees. The data presented indicate in general where fruit which is representative of average fruit on a given tree may be found. The size of the block and the accuracy of results desired will govern the size of the sample which must be taken.

Special problems in sampling may arise in which the trees to be sampled are nonsymmetrical due to planting in hedgerows, or in which the lower branches of the tree have been removed following the overlapping of the branches from adjoining trees, or for other reasons. Another type of problem concerns the location of the major proportion

of the crop in the tree. In the single Valencia tree studied, approximately one-third of the entire crop was classified as canopy fruit. Such a proportion of fruit will not always occur in the canopy. In some cases the majority of fruit will be found inside the canopy of the foliage, while in other cases the majority of the fruit will lie outside the canopy. Obviously the methods of sampling proposed above cannot be applied to these conditions without some modification. Adjustments should be made in the sampling methods so that the fruit sampled is typical of the crop as a whole.

Aside from the accuracy of sampling, the extent to which internal quality may be improved by spot-picking is of value to the commercial grower and packinghouse operator. It would be helpful to know approximately how much the average per cent soluble solids of the fruit from a given block of trees might be increased by not picking fruit from portions of the tree which produce fruit with a low soluble solids content. By so doing a grower might dispose of a portion of his crop at a high price early in the season, and leave the remainder of the fruit to be picked later. Table II was prepared from these data to show what

TABLE II—THE EFFECT OF SPOT-PICKING CERTAIN PORTIONS OF THE TREE UPON THE AVERAGE SOLUBLE SOLIDS IN THE JUICE OF THE FRUIT OBTAINED

Section of Tree Not Included	Per Cent of Total Fruit Included	Average Per Cent Soluble Solids of Fruit Included
——	100.0	10.24
Inside	82.1	10 57
Top inside	92 3	10.26
Canopy	67 6	10.34
Inside and top inside	74 4	10.64
Inside, top inside and canopy	41.9	11.12
Inside and lower 2 feet of canopy	79.9	10.60
Inside and lower 4 feet of canopy	77.3	10.64
Inside and lower 6 feet of canopy	73.9	10.69
Inside and lower 6 feet of canopy and lower 2 feet of outside	73.6	10.70
Inside and lower 6 feet of canopy and lower 4 feet of outside	73.3	10.70
Inside and lower 6 feet of canopy and lower 6 feet of outside	70.4	10.73

actual increases were obtained where this was done. Spot-picking in this manner whether to improve the quality or to comply with maturity regulations would appear to be a practical and useful operation in commercial practice. The amount of spot-picking necessary in any grove would depend upon the difference between the level of soluble solids desired in the picked fruit and the average soluble solids level of the grove-run fruit. In many instances, leaving only the inside fruit might increase the soluble solids sufficiently to meet the minimum standards.

It may be argued that these generalizations are too broad to be based on the results of a single tree. The authors wish to point out, however, that this is a detailed study of concepts which were first arrived at through the study of a larger number of trees in less detail. In addition, the effect of shade has been substantiated by other workers. There may be some variation between varieties, but since all commercially important varieties grown in Florida tend to form dense canopies, the variation between varieties should not be great. Since fundamentally

these differences appear to be associated with variations in intensity and duration of light and its consequent effect on the fruit and on carbohydrate production by the leaves, there is little reason to believe that the general relationships will vary greatly between varieties or between trees of the same variety. It is probable that composition of the juice of fruit produced on young trees will not be influenced as greatly by position on the tree as in older trees.

Summary

1. Extreme variation in the soluble solids content of the juice of Valencia oranges from the same tree was found to be related to position of the fruit on the tree. (a) Fruit with the highest soluble solids in the juice was "top outside" fruit, (b) fruit with lowest soluble solids in the juice was "inside" fruit, and (c) fruit from other portions of the tree was intermediate in soluble solids content.

2. The per cent soluble solids content of the fruit varied with the amount of shading, the height of the fruit on the tree, the direction of exposure to light, and the color of the rind.

3. Sampling techniques for sampling large and small lots of trees are proposed.

4. Suggestions for spot-picking oranges to include only high quality fruit are presented.

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Investigations on the Use of Iron Sprays, Dusts, and Soil Applications to Control Iron Chlorosis of Citrus

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THE use of iron sprays to correct iron deficiency has proven successful with some plants, notably the pineapple, but results with citrus trees to date have been rather unsatisfactory. When iron sprays, such as ferrous sulfate, are applied to iron chlorotic citrus leaves, complete or sheet greening of the leaf does not occur. Instead, small green spots appear, as shown in Fig. 1. Since it is evident that some of the applied iron penetrates the leaf and becomes effective in local areas, it seemed reasonable to believe that a form of iron might be found, or a combination of iron and spreading agents, or a method of application worked out, which would produce complete greening of chlorotic leaves. Accordingly, a wide range of iron compounds, some organic and some inorganic were applied to chlorotic orange, grapefruit, and lemon foliage in various concentrations, with and without spreading agents, and at various pH values. Various iron dust compounds and combinations were also tried. In addition, different techniques of foliage application were studied. Because of occasional reports by growers that iron chlorosis has been corrected by soil application of iron compounds, trials of this nature were also initiated.

DISTRIBUTION OF IRON CHLOROSIS OF CITRUS

In California, a great deal of iron chlorosis occurs on lemon plantings in Ventura and Santa Barbara counties. In certain parts of Orange County, particularly the Garden Grove section, iron chlorosis is serious on oranges. It occurs locally and to a greater or lesser degree in many other citrus sections. In all or nearly all of these regions chlorosis is more severe in the winter and early spring. It is worse in some years than others. Because of the perennial nature of this trouble, its rather wide occurrence, lack of satisfactory control methods, and the probability that to some degree at least other citrus problems are probably aggravated by the disorder, it seemed worth while to investigate the problem further.

CAUSES OF IRON CHLOROSIS

Despite a very considerable amount of research, the cause or causes of this disorder are not clear. Lime-induced iron chlorosis is widespread and is thought by many to result from the soil alkalinity and buffering of soils imparted by lime. However, not all calcareous soils produce iron chlorosis and plants are extremely variable as to susceptibility. Iron chlorosis also occurs on noncalcareous soils. Among the factors other than free lime which in the authors' experience may produce or play a part in iron chlorosis of citrus are: (a) excessive soil moisture; (b) cold soil temperatures; (c) excessive phosphate; (d) potash deficiency; (e) magnesium deficiency; (f) excessive zinc;

FIG. 1. Typical response of iron chlorotic citrus leaves when sprayed with iron sulfate solution without spreader. These are grapefruit leaves and were sprayed June 9, 1947, with a solution containing 2 pounds iron sulfate per 100 gallons of water. Picture taken August 15, 1947.

(g) excessive soluble salts; and (h) possibly soil organisms. Since so many factors, singly or in combination may cause iron chlorosis of citrus, it seemed all the more worth while to explore the possibility of developing a spray, for in the writers' experience no matter what the cause, iron sulfate solutions sprayed on foliage showing typical iron deficiency patterns invariably bring about a certain amount of improvement.

EXPERIMENTAL

Effectiveness of Various Wetting Agents:—Prior to testing the large number of iron compounds referred to, the effectiveness of various spreading agents was tested. Seven different spreading agents were procured and after determining the amount which, in combination with iron sulfate (2 pounds per 100 gallons) would satisfactorily wet orange and lemon leaves, trials on iron chlorotic and lemon shoots were undertaken. A list of wetting agents tried and the amounts used per 100 gallons of final spray solution is shown in Table I. All seven

TABLE I—KINDS AND AMOUNTS OF WETTING AGENTS USED IN PRELIMINARY TESTS

Wetting Agent	Rate of Application (Per 100 Gallons of Spray)
Vatsol (85 per cent O T.)	2.08 pounds
Vatsol (33 per cent O T. 100)	3.34 pounds
Blood albumin	2.00 pounds
Triton B-1956	15.4 liquid ounces
Triton X-155	153.6 liquid ounces
Triton X-300	76.8 liquid ounces
Triton X-400	6.01 pounds

of these materials were tried respectively with the following iron compounds: ferrous sulfate, c.p., ferrous lactate, and ferrous bromide.

In order to insure a maximum coverage, and at the same time avoid contamination of nearby foliage, the technique of treatment consisted in selecting apical, iron chlorotic shoots and dipping these into the test solution. Usually five such shoots were treated with a given solution and the shoot tagged to show the date and kind of solution used. Untreated shoots of about the same degree of chlorosis served as checks. At periodic intervals following treatment, the shoots were inspected both as regards kind and degree of greening, and as well injury, such as leaf abscission, and necrosis. The changes noted were evaluated in terms of the untreated checks.

In general, the effect of the spreaders was to produce a greater degree of leaf greening and to reduce necrotic spotting. In few if any instances however did chlorotic leaves become completely green. Fig. 2 illustrates the typical results obtained with and without spreading agents.

Of the various spreaders used, Vatsol was definitely superior to all the others but as noted repeatedly throughout this work, injury was greater. That is, the sprays most effective as regards greening were also the most injurious. Blood albumen was the least effective of the spreaders. In general, it was noted that the upper side of leaves wet better than the lower side and that orange leaves wet better than lemon leaves.

Comparison of Iron Compounds:—Thirty-eight different iron compounds were applied in three concentrations, with and without Vatsol, and at three pH values, respectively, to iron chlorotic orange leaves. Thirty-three of these compounds were also tried using a similar technique on chlorotic lemon shoots. At each of the low, medium, and

TABLE II—IRON COMPOUNDS USED FOR LEAF DIPPING TESTS (ALL APPLIED SUMMER OR FALL, 1946, TO ORANGE OR GRAPEFRUIT FOLIAGE)

Compound or Trade Name	Chemical Formula or Description*	Base Solution (Low Concentration) Lbs/100 Gals	Designation	pH of Solution With Vatsol (No. 2 Solution)	Results by Nov 8, 1946	
					Degree of Leaf Greening†	Degree of Injury
Ferrous sulfate	$FeSO_4.7H_2O$	2 0	A	4.7	++ to +++	None?
Ferrous chloride	$FeCl_2.4H_2O$	1.4	B	3.8	+++	Moderate to severe
Ferric chloride	$FeCl_3.6H_2O$	1 9	C	2.8	+	Moderate
Fermate	Ferric dimethyldithio carbamate	2.0	D	5.4	+	None
Fermate and zerlate	Ferric dimethyldithio carbamate and zinc dimethyldithio carbamate	2.0 2.0	D1	6.8	0 to +	None
Fermate and sulfur		2.0 0.5	D2	4.5	0	None
Fermate, zerlate, and sulfur		2.0 2.0 1.0	D3	5.9	0	None
Gelofer	A ferric-silicic-colloidal complex	2.0	G	8.6	0	None
Gelofer (ground)	A ferric-silicic-colloidal complex (ground in a ball mill)	2.0	H1	9.2	0	None
Magnetite	Fe_3O_4	2.0	H	5.9	0	None
Magnetite and sulfur	Fe_3O_4 and sulfur	2.0 plus 0.5	H1	5.3	0	None
Ferrous ammonium sulfate	$FeSO_4(NH_4)_2SO_4.6H_2O$	2.8	E	5.1	++	Slight to moderate
Ferric ammonium sulfate	$Fe_2(SO_4)_3(NH_4)_2SO_4.24H_2O$	3.4	F	3.1	+	Slight
Ferric ammonium citrate	(Est. 16.5 per cent Fe)	2 3	I	7.3	++	Moderate
Ferric potassium oxalate	$K_3Fe(C_2O_4)_3.3H_2O$	3.5	J	4.2	+ to ++	None
Ferric citrate	$FeC_6O_5O_7.5H_2O$ ±	2.4	K	4.0	+	None to slight
Ferrous carbonate-saccharated	(Est. 15 per cent $FeCO_3$)	5.5	L	5.9	0	None
Iron peptonized	(Est. 25 per cent Fe_2O_3)	2.3	M	7.8	+	None
Ferric phosphate soluble	(Est. 13.5 per cent Fe)	3.5	N	3 3	+	None
Ferric glycero phosphate	$Fe[C_3H_5(OH)_2PO_4]_3$	2.2	O	5.8	+	None
Ferric hypophosphite	$Fe[H_2PO_2]_3$	1.8	P	2.9	0 to +	None
Ferric ammonium oxalate	$(NH_4)_3Fe(C_2O_4)_3.3H_2O$	3.1	Q	4.7	+	None to Slight
Hemin	$C_{34}H_{32}N_4O_4FeCl$	4.7	R	4.5	0	None
Ferrous lactate	$Fe(C_3H_5O_3)_2.3H_2O$	2.0	S	5.2	++ to +++	None?
Ferrous oxalate	$FeC_2O_4.2H_2O$	1.3	T	5.2	0	None
Ferrous bromide	$FeBr_2.2H_2O$	1.8	U	2.9	+++	Slight to moderate
Ferrous iodide	$FeI_2.4H_2O$	2.7	V	3.7	+++	Slight to moderate
Ferric tartrate	$Fe(C_4N_4O_6)_3.H_2O$	2.0	W	6 1	+	None

Ferric potassium tartrate	$K(FeO)(C_4H_4O_6)^+H_2O$	2.2	X	7.6	+	None
Ferric albumate	(5 per cent Fe_2O_3)	11.3	Y	7.5	0 to +	None
Ferric sulfate	$Fe_2(SO_4)_3$	1.4	Z	2.6	+ to ++	Moderate
Ferric cacodylate	Approximately $Fe[(CH_3)_2AsO_2]_3$	3.3	AA	5.6	0 to +	Severe
Ferric nitrate	$Fe(NO_3)_3.9H_2O$	2.9	BB	2.4	+	Moderate
Ferric ammonium tartrate	$Fe_2O_3(C_4H_4O_6)_3$ 2NH $9H_2O$	2.3	CC	6.8	+	—
Ferric sodium oxalate	$FeNa_3(C_2O_4)_3$.4 ½ per cent H_2O	3.3	DD	5.0	++	Severe
Ferric manganese citrate	(Established 12.5 per cent Fe)	3.2	EE	5.5	+	Severe
Ferric tannate	(Established 9 per cent Fe)	4.4	FF	3.3	+	Severe
Ferric benzoate	Approximately $Fe(C_6H_5CO_2)_3Fe(OH)_3.6H_2O$	2.3	GG	3.7	0	None
Ferric valerate	Approximately $FeC_5H_9O_2(OH)_2$ +30 per cent H_2O	2.0	HH	3.6	0	None
Ferric strychnine citrate	(Established 16 per cent Fe)	2.5	II	3.0	+	Slight
Ferric potassium citrate	(Established 16 per cent Fe)	2.5	JJ	3.6	+	Slight
Ferric potassium sulfate	(Established 15 per cent Fe)	2.7	KK	1.8	+	Slight
Iron 8-quinolinolate		2.0	LL	3.5	0	None

*For further descriptions of some of these compounds refer to Merck Index.

†The degree of greening is denoted as follows: 0 = no greening; + = slight evidence of greening, such as a few green dots or small spots; ++ = moderate evidence of greening, such as numerous green spots; +++ = considerable greening that is, leaves 75 to 90 per cent green, but some evidence of chlorosis still apparent; ++++ = leaf entirely green.

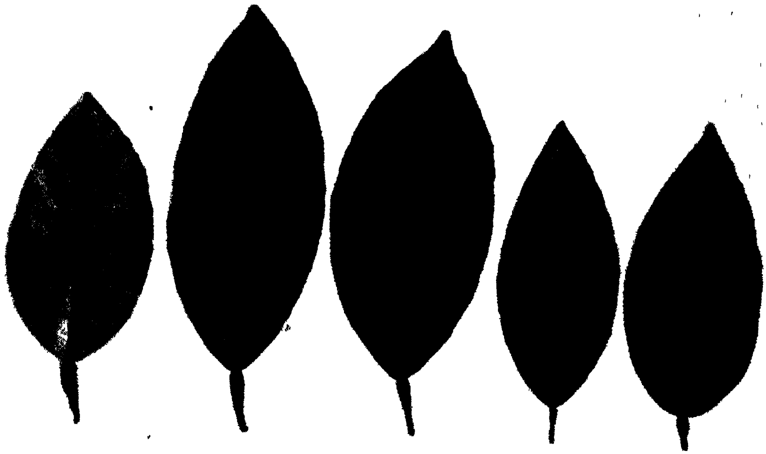

FIG. 2. Shows effect of iron sprays with and without spreader. Leaf on left unsprayed; two center leaves sprayed with iron sulfate containing spreader (Vatsol); two leaves on right, no spreader. Note necrotic spotting of leaf on right. The use of spreaders in general reduced this kind of injury but did not prevent leaf abscission. In general, the more effective the spray in terms of greening, the greater its injury in terms of necrosis and leaf abscission.

high concentrations the following solutions were prepared: 1, iron compound, no pH adjustment, no Vatsol; 2, iron compound, no pH adjustment plus Vatsol; 3, iron compound, Vatsol, pH adjusted to 3.0; 4, iron compound, Vatsol, pH adjusted to 5.0; and 5, iron compound, Vatsol, pH adjusted to 7.0. Thus, for each iron compound tested, 15 different solutions were prepared and each applied to five replicate shoots.

The results of these trials using the No. 2 solution (iron compound, Vatsol, no pH adjustment) are shown in Table II.

As may be seen from Table II, complete greening of chlorotic leaves was not obtained in any case. The most effective materials were ferrous sulfate, ferrous chloride, ferrous bromide, and ferrous iodide. It is of interest that the organic forms of iron were in general not as effective as the inorganic forms save that ferrous lactate gave results almost as good as the above named. A number of iron compounds produced no greening whatsoever. As noted previously, greening in most cases was improved by the use of the wetting agent.

In general, the solutions which brought about the greatest degree of recovery also produced more leaf injury. This took the form of necrotic spots or blotches.

With regard to the effects of pH, save in a few instances, greening of chlorotic leaves was not enhanced by adjusting the reaction of the spray solution prior to use of pH 3.0. When the pH was raised to 7.0 however, the extent of greening was usually reduced. At the latter pH, there was little leaf injury. The evidence as regards pH sug-

gests that, in general, a given iron spray is more effective if the solution is on the acid side. (Values between pH 4.5 and 5.5 gave the best results). High concentrations of iron compounds were no more effective than the lowest concentration used. (The base rate for the low concentration was 2.0 pounds ferrous sulfate or equivalent per 100 gallons of spray).

Perhaps the most disappointing aspect of this work was the observation that new growth cycles emerging from treated shoots were just as chlorotic as the foliage of a particular shoot prior to treatment. This indicates that the iron which gains entrance into the leaf is effective in chlorophyll formation only in that leaf, and its effectiveness is not carried over into new developing shoots. Fig. 3 shows the failure of new growth cycles to improve even though a substantial degree of improvement resulted from dipping the original shoot in an iron solution. Of course this does not mean that no over-all improvement in tree condition would result from an iron spray. Had it not been for the spray perhaps *no* new growth would have emerged and the chlorotic twig would have died back. It is evident however that a program of frequent spraying would be necessary to sustain the somewhat improved foliage condition.

Great differences in the degree of greening of different leaves on the same shoot were consistently noted. In general, young leaves responded more rapidly and completely than old leaves. Greening of leaves from a given spray was more rapid and complete in summer than in winter. Typical of the maximum degree of greening secured from any of the treatments is that shown in Fig. 4. This corresponds to the (+++) rating as defined in Table II.

Effect of Wetting the Upper Versus the Lower Surface of Leaves:— To determine the relative effectiveness of iron applied to the lower versus the upper side of orange and lemon leaves a series of tests were made with ferrous sulfate, ferrous lactate, and ferrous bromide all with Vatsol spreading agent. The iron sulfate was used at a rate of 2 pounds per 100 gallons of solution and the other compounds on an equivalent basis; the Vatsol was used at a rate of 2.08 pounds per 100 gallons of spray. Tests were made on both lemon and orange leaves affected with iron chlorosis. The following methods of treating the leaves were compared: (a) dipping the whole shoot; (b) painting both sides of the leaf; (c) painting the upper side only; and (d) painting the lower side only.

With orange leaves, the amount of greening was almost as great when the lower side of the leaf only was treated as when both sides were painted. With the lemon, the results were less conclusive but in the same direction. This indicates either that more iron is absorbed through the lower surface of the leaf than the upper or that the iron penetrating through the lower surface is more effective in chlorophyll formation. Whatever the explanation, in spraying, thorough coverage of the lower surface of the leaf is desirable.

Spray Trials on Entire Tree:—In the summer of 1947, both orange and lemon trees were sprayed with those iron compounds which gave the best results in the dipping tests, namely, ferrous sulfate, ferrous

FIG. 3. Shows iron chlorosis of new cycle growth which emerged following spray treatment and partial recovery of old cycle. This indicates that, though iron sprays bring about some recovery of treated leaves, there is no apparent benefit in so far as chlorosis is concerned to succeeding growth cycles.

bromide, ferrous iodide, and ferrous lactate. Spray solutions were made up at the rate of 2 pounds of iron compound per 100 gallons of water except that ferrous bromide was used at the rate of 3 pounds per 100 gallons. Vatsol at a rate of 1 pound per 100 gallons was also incorporated in the spray. In a few cases the iron compounds were made up with a regular pest control light-medium oil spray (1¾ per cent), omitting the spreading agent in this case. The trees were thoroughly wetted with the spray, a commercial spray rig being used in these tests. The results of the spray treatments to entire trees were es-

FIG. 4. Shows degree of recovery of iron chlorotic shoots sprayed with ferrous lactate plus Vatsol spreader, 2 pounds of iron salt, and 2.08 pounds of Vatsol per 100 gallons of water. This corresponds to the (+++) rating as noted in Table II. (Left—Sprayed shoot; Right—Unsprayed check)

sentially the same as with the dipping trials. In most cases a substantial amount of leaf greening occurred, but in few if any cases were chlorotic leaves completely cured. Moreover, ensuing growth cycles were again iron chlorotic. More or less necrotic spotting of leaves and young fruit occurred, the degree of this being roughly parallel to the degree of greening. Mature fruits were not injured. The type of injury produced on young fruit is shown in Fig. 5.

Use of Iron Dusts:—A number of iron compounds were applied as dusts rather than in spray form[1]. These were applied with and without dusting sulfur as a diluent and also to chlorotic shoots which had in some cases been dipped in a Vatsol solution prior to applying the dust. The compounds used were Gelofer (a ferric-silicic colloidal complex furnished to the authors through the courtesy of the French Potash and Import Company, Inc.), fermate, fermate and zerlate combined, and magnetite. In all instances, these tests were more disappointing than those with iron compounds applied as sprays.

Injection Treatments:—Iron solutions have been injected into iron chlorotic citrus trees by pressure apparatus following somewhat the same technique as used by Southwick (3). These trials have confirmed

[1]While this investigation was under way two papers were published by Haas and Zentmyer (1, 2) reporting striking improvement in iron chlorosis of lemon cuttings from the application of magnetite and sulfur dusts and other combinations. These results were obtained on plants grown under greenhouse conditions. Trials of these same materials under field conditions gave disappointing results as may be seen by reference to Table II.

FIG. 5. Shows fruit injury from iron sulfate spray. In general, the more effective the spray from the standpoint of clearing up the leaf chlorosis, the more injurious it is to young fruit. Mature fruits are not injured however.

the findings of Southwick that correction can be obtained. However, the necessity for repeated treatments after a few years, the costs involved, together with the danger of infection and injury to the tree trunk render this method of rather dubious value.

Soil Treatments:—Solutions of iron sulfate were injected into the soil under pressure through a hollow probe equipped with a perforated nozzle using a conventional spray rig. Amounts ranging from 10 to 80 pounds of iron sulfate per tree were injected into the root zone. The iron to be injected was dissolved in 200 gallons of water, thoroughly agitated, and injections made by inserting the probe at several hundred points under and around the drip of the tree. By this means

it is certain that a good distribution of the dissolved iron was effected. There were three replications of each concentration in each location. Three different orchards were used in this study--one on a Hanford loam near Redlands; another on a Hanford sandy loam near Garden Grove; and the third on a lemon orchard in Ventura County located on a Yolo clay loam. Systematic observations have been made over a period of two years. To date no evidence of real improvement in the degree of chlorosis present has been noted.

Discussion and Conclusion

While it is possible to effect a considerable amount of foliage correction by the use of ferrous sulfate as well as a number of iron compounds in combination with a good wetting agent, repeated sprayings, possibly two or three a year, would be needed to keep the tree in a permanently improved condition. Unfortunately, a certain amount of fruit injury (necrotic spotting of rind) occurs in young fruit, and there is also some leaf injury with those compounds or combinations most effective as regards leaf greening.

Despite the somewhat disappointing outcome of this work, the use of iron sprays with a good wetting agent such as Vatsol, could probably be used to advantage where iron chlorosis is severe. Since results with iron sulfate were nearly as good as with any of the other iron compounds, and since it is cheaper than any of the other iron sources, it is suggested for further field trials and testing that this material be used at a rate of 2 pounds per 100 gallons of water and that Vatsol at a rate of 1 pound per 100 gallons also be included in the spray formula.

Mention should again be made of the fact that in many instances better control of soil moisture has brought about substantial improvement in quite a number of iron chlorotic orchards. Growers who are confronted with this problem in their orchards should make every effort to avoid overirrigation and to modify their irrigation methods so as to minimize prolonged over moist conditions in the root zone.

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The Effect of Nitrogen, Phosphorus, and Potassium Upon the Growth of Newly Transplanted Tung Trees[1]

By BENJAMIN G. SITTON, *U. S. Department of Agriculture, Bogalusa, La.*

MOST tung trees pruned and trained to a single trunk, the so-called natural head, make a strong well-formed frame or "head" if growth is vigorous and branching occurs before the end of the first growing season. On the other hand tung trees that do not branch the first year in the orchard produce a very weak and undesirable whorl of closely spaced branches from the apical buds when growth is resumed the second year, unless the terminal portion is pruned away so as to force lateral buds into growth. A high rate of growth during the first year in the orchard is particularly important in tung, therefore, to obtain well formed trees.

A series of seven experiments were conducted to study the effect of nitrogen, phosphorus, and potassium fertilizers upon this all-important growth of tung the first season in the orchard. The experiments were located near Franklinton, Folsom, and Pine, Louisiana in 1944; near Carriere and Lumberton, Mississippi in 1945; and near Enon, Louisiana, and Poplarville, Mississippi in 1946. The experiments at Pine and Carriere were on Ruston sandy loam, those at Folsom and Poplarville on Norfolk fine sandy loam, the one at Lumberton was on Norfolk fine sand, the one at Enon on Dulac loam and the one at Franklinton on Lewiston silt loam. The seven experiments are thus located in Washington and St. Tammany Parishes in Louisiana, and in Pearl River County, Mississippi, and constitute a representative cross section of the area in eastern Louisiana and southern Mississippi in which approximately 75 per cent of the tung acreage of the United States is located.

The tung trees were transplanted from the nursery into the orchard during the winter months, some as 1-year-old seedling trees and some as budded trees having 1-year-old clonal tops and 2-year-old seedling roots. Trees were pruned to the vase form in the 1944 experiments and to the natural head in the 1945 and 1946 experiments. Although there were minor variations between seedling and clonal trees, it appears unessential to present the data separately.

The fertilizers were applied in a circular band around and about 12 to 15 inches from the trunks of the trees soon after they started growth. Three levels each of nitrogen, phosphorus, and potassium were used. The low level of each was that supplied by the soil, except that in 1946 an additional 0.04 pound of nitrogen was applied per tree. At the intermediate levels, 0.08 pound of N, 0.08 pound P_2O_5, and 0.06 pound K_2O were applied per tree; and at the high levels the amounts were twice those used at the intermediate level. Nitrogen was supplied as

[1]The writer is indebted to Dr. George F. Potter, principal physiologist, Bogalusa, Louisiana, for his assistance in planning the experiments and for his review of the manuscript; and to Dr. Matthew Drosdoff, soil technologist, Gainesville, Florida, for the leaf analyses.

ammonium nitrate, phosphorus as 20 per cent superphosphate, and potassium as 50 per cent muriate of potash.

Each of the seven experiments was set up in a balanced partially confounded factorial design with four replications of 27 treatments, representing all possible combinations of the three levels of the three elements (6). Each replication was subdivided into three blocks of nine treatments each. Each treatment plot consisted of four trees.

Samples of leaves were collected in August in the experiments at Franklinton, Carriere, Lumberton, and Poplarville. Forty-eight leaves per plot were removed without petioles from the mid-portion of the primary shoots of the trees in each plot receiving the low and the high levels of each element. Nitrogen, phosphorus, and potassium were determined by methods described by Drosdoff (1).

Measurements of total linear growth were made after the completion of the first growing season.

As might be expected the differences in soil, in cultural treatments, and in weather during the three summers resulted in differences in growth of the trees not entirely associated with the fertilizers applied. In order to obtain an over-all picture of the response of the trees to fertilizers the data from each of the seven experiments were first analyzed separately; then they were pooled in a single analysis, even though the data for the several locations are less homogeneous than desirable. Under these circumstances the pooled error term is probably rather high in relation to average growth responses to the fertilizers.

Results

The pooled data showed a highly significant difference between locations and a highly significant interaction between locations and treatments. A considerable part of the difference between locations can be accounted for by variations in weed control by the cooperators. The newly planted tung tree is very sensitive to weed competition (2, 3, 4, 5). At Pine no cultivation or hoeing was done until July, when the weeds were taller than the trees, especially at the high levels of nitrogen. At Carriere the tree rows were disked but the trees were not hoed, so that weeds grew immediately around the trees. At Poplarville the trees were disked and hoed once, but weeds developed, which interfered with growth. At Lumberton the Norfolk fine sand was low in available moisture most of the time.

The Effect of Nitrogen:—The pooled data of the seven experiments show that the intermediate level of nitrogen resulted in an average increase in total linear growth of 55 centimeters, or 13.6 per cent more than that made by the trees at the low level of nitrogen, a significant increase (Table I). The high level of nitrogen resulted in a non-significant increase of 10 centimeters over that made at the intermediate level. The intermediate level of nitrogen resulted in increased linear growth over that made at the lower level at all locations except Lumberton, although only at Franklinton and at Poplarville were the differences great enough to attain statistical significance. At these two locations the high level of nitrogen resulted, respectively, in 31.7 and 28.6 per cent more growth than that made at the intermediate level.

TABLE I—THE EFFECT OF NITROGEN, PHOSPHORUS, AND POTASSIUM UPON FIRST YEAR LINEAR SHOOT GROWTH OF NEWLY TRANSPLANTED TUNG TREES AT SEVEN LOCATIONS IN LOUISIANA AND MISSISSIPPI (1944–1946)

Fertilizer Applied Element	Amount Per Tree (Lbs)	Pine 1944 (Cms)	Folsom 1944 (Cms)	Franklinton 1944 (Cms)	Carriere 1945 (Cms)	Lumberton 1945 (Cms)	Enon 1946 (Cms)	Poplarville 1946 (Cms)	Average All Locations (Cms)
Nitrogen	0.00	120	564	235	434	338	533	214	348
	0.08	134	567	539	464	289	546	279	403
	0.16	126	531	710	432	245	514	331	413
	F found	2.33	—	73.37***	—	4.91**	1.32	19.69***	4.07*
Phosphorus	0.00	117	455	498	446	230	336	246	332
	0.08	126	586	520	427	319	574	274	404
	0.16	137	621	465	458	322	683	304	427
	F found	4.63*	5.01**	—	—	6.23**	158.11***	4.91**	8.30**
Potassium	0.00	136	495	401	429	304	551	277	371
	0.06	129	605	508	438	298	526	270	396
	0.12	114	563	574	463	269	516	278	397
	F found	5.51**	1.99	9.72***	—	—	1.67	—	—
Least difference significant at	0.05	13	82	79	68	59	40	37	48
	0.01	18	108	105	90	79	53	49	64
	0.001	23	141	137	117	103	69	64	82

F needed for significance for individual locations: at .05, 3.13, at .01, 4.92; at .001, 7.76; and for pooled data, using interaction of location by treatment mean square as error for testing: at .05, 3.07; at .01, 4.79, and at .001, 7.31.

The high level of nitrogen resulted in less growth than the intermediate level at all the other locations. The failure of the high level of nitrogen to produce growth equal to or greater than the intermediate level probably indicates that the limited root area of the newly transplanted trees was unable to utilize all of the nitrogen supplied, or even that the high level was injurious to the tree. The extra nitrogen may well have an adverse effect through stimulating the growth of competing weeds, as has been previously mentioned, and thus increasing the competition for moisture and nutrients.

The Effect of Phosphorus:—When data from all locations are pooled the intermediate level of phosphorus resulted in an average increase in total linear growth of 72 centimeters, or 21.7 per cent over that made by trees at the low level. The increased growth resulting from the first increment in phosphorus applied was greater than needed for significance, but the increase resulting from the high level of phosphorus over that made by trees at the intermediate level was nonsignificant.

Increases in linear growth at the intermediate level of phosphorus over the growth at the low level were found at every location except Carriere. At all locations except Franklinton, the high level of phosphorus resulted in increased growth over that made at the intermediate level; but only at Pine and Poplarville was the increase resulting from the second increment equal to that resulting from the first increment. At Enon the increase at the second increment of phosphorus was approximately half the increase at the first increment. At Carriere the trees that received the first increment were smaller than trees receiving no phosphorus, but those at the high level showed an increase in growth.

The Effect of Potassium:—The pooled data for the seven locations show no significant effect of the different levels of potassium on linear growth. At Franklinton there was a highly significant increase and at Pine a highly significant decrease in linear growth associated with potassium applications. Nonsignificant increases resulted at Folsom and Carriere, and nonsignificant decreases at Lumberton and Enon, with no difference at Poplarville.

Nitrogen in Leaves:—The application of 0.16 pound of nitrogen per tree to the soil resulted in a highly significant increase in the percentage of nitrogen in the leaves, sampled in August at four locations (Table II).

At Franklinton and at Poplarville the nitrogen content of leaves on trees to which no nitrogen had been applied was close to the deficiency range. There both the nitrogen content of the leaves and the growth of trees were increased at the high level of nitrogen. At Carriere the nitrogen content of the leaves from trees at the low level of nitrogen was within the range usually considered optimum for tung. There the high level application increased the nitrogen content of the leaves but failed to improve growth over that made at the low level. At Lumberton, where the nitrogen content of leaves from trees at the low level of nitrogen was above the optimum range, the high nitrogen appli-

TABLE II—COMPOSITION OF TUNG LEAVES SAMPLED IN AUGUST IN RELATION TO FERTILIZATION WITH NITROGEN, PHOSPHORUS, AND POTASSIUM (DRY BASIS)

Element	Amount Per Tree (Lbs)	Nitrogen				Phosphorus				Potassium			
		Franklinton	Carriere	Lumberton	Poplarville	Franklinton	Carriere	Lumberton	Poplarville	Franklinton	Carriere	Lumberton	Poplarville
		(Per Cent)	(Per Cent)	(Per Cent)	(Per Cent)	(Per Cent)	(Per Cent)	(Per Cent)	(Per Cent)	(Per Cent)	(Per Cent)	(Per Cent)	(Per Cent)
Nitrogen	0.00	1.94	2.25	2.54	1.92	0.158	0.161	0.151	0.159	0.781	0.757	0.869	0.685
	0.16	2.51	2.89	3.05	2.30	0.165	0.162	0.166	0.169	0.780	0.721	0.850	0.553
Phosphorus	0.00	2.25	2.68	2.87	2.13	0.148	0.166	0.150	0.164	0.801	0.744	0.896	0.599
	0.16	2.19	2.46	2.72	2.08	0.169	0.157	0.168	0.164	0.752	0.733	0.823	0.639
Potassium	0.00	2.22	2.55	2.79	2.14	0.163	0.166	0.165	0.164	0.603	0.599	0.725	0.492
	0.12	2.22	2.59	2.80	2.08	0.161	0.157	0.153	0.164	0.894	0.879	0.994	0.746
Least difference significant													
At 0.05	—	0.06	0.14	0.22	0.16	0.008	—	0.006	0.016	0.028	0.073	0.103	0.130
At 0.01	—	0.08	0.19	0.30	0.22	0.010	—	0.008	0.021	0.038	0.099	0.140	0.178
At 0.001	—	0.11	0.26	0.41	0.29	0.014	—	0.011	0.029	0.051	0.134	0.189	0.239

cation again increased nitrogen in the leaves but depressed growth of the trees.

Phosphorus in Leaves:—The percentage of phosphorus in the leaves of tung trees sampled in August at Lumberton and at Franklinton was significantly greater at the high level of phosphorus than at the low level. At Poplarville and at Carriere leaves from trees at the low level of phosphorus were high in phosphorus, .164 and .166 per cent. Here the supplementary application effected no increase in phosphorus in the leaves. There was no consistent relationship between the phosphorus content of the leaves in August and the growth of the trees.

Potassium in Leaves:—At each location the high level of potassium fertilizer very significantly increased the percentage of potassium in the leaves over that at the low level of potassium fertilizer, but there was no consistent relationship between the potassium content of the leaves and growth of the trees.

Conclusions

In the Mississippi and Louisiana tung growing areas, it is of greatest importance to fertilize newly planted tung trees with phosphorus in amounts ranging from 0.08 to 0.16 pound of P_2O_5 per tree.

Nitrogen at the rate of 0.08 pound per tree also promotes tree growth under most conditions; but an excess of nitrogen may depress growth, especially if the soil is fairly rich in that element.

Potassium only rarely improves growth, and may significantly depress it; but with lack of definite knowledge for the specific location, an application of 0.04 pound per tree seems advisable.

Summary

Three levels each of nitrogen, phosphorus, and potassium fertilizers were applied to newly transplanted tung trees on various soil types at seven locations in Mississippi and Louisiana tung-growing districts, in 1944, 1945 and 1946.

At six of the seven locations the intermediate level of nitrogen, 0.08 pound per tree, resulted in greater linear growth of the trees than that made by trees at the low level of nitrogen; but the high level, 0.16 pound of nitrogen per tree, improved growth over the intermediate level at only two locations.

The effect of nitrogen on growth was rather consistently correlated with nitrogen content of the leaves. Where leaves of unfertilized trees contained 1.92 to 1.94 per cent of nitrogen, 0.16 pound of nitrogen per tree markedly improved growth; where the leaves of check trees contained 2.25 per cent of nitrogen, there was little or no improvement in growth; and where leaves of check trees contained 2.54 per cent of nitrogen, additional applications depressed growth.

The intermediate level of phosphorus, 0.08 pound P_2O_5 per tree, resulted in greater linear growth of tung trees than that made at the low level of phosphorus, at six out of seven locations; and the high level of phosphorus, 0.16 pound P_2O_5 per tree, improved linear growth in comparison with that made by the trees at the intermediate level of phosphorus, in all locations except one.

The effect of potassium upon the growth of tung trees was incon-

sistent; at three locations growth was improved, at three it was depressed, and at one it was not affected.

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Soil Moisture and Growth of Apple Trees[1]

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RESEARCH workers, for several years, have held conflicting opinions in regard to the utilization of soil moisture by fruit crops. In this respect there appears to be two schools of thought. One school maintains that there is little or no reduction in growth and yield of fruit crops before all of the available soil moisture is depleted, whereas the other maintains that a very marked reduction in growth and yield of fruit crops occurs before all available soil moisture is utilized.

Considering the physiological behavior of plants (19) together with the physical properties of soils, a reduction in growth or production of fruit trees should occur, theoretically, before all of the available soil moisture is depleted.

In regions where irrigation is practiced or where periods of drought are frequent, a better understanding of the influence of soil moisture depletion would aid fruit growers in determining the need for irrigation. A study was initiated at Pullman, Washington, in 1941 in an effort to determine the effect of soil moisture upon the growth of apple trees.

REVIEW OF LITERATURE

Hendrickson and Veihmeyer have maintained in several reports (8, 9, 10, 11, 12) that, under California conditions, various fruit crops growing in sandy soils do not suffer from gradual drying of the soil, but are able to obtain moisture readily until the permanent wilting point is approached. This conclusion is based upon observations concerning yield, size of fruit, or rate of fruit enlargement. Size of tree, however, was found to be reduced before the permanent wilting point was reached (8, 9). In general, their tests were conducted by comparing an irrigated plot with a non-irrigated plot. The soil moisture in the non-irrigated plot usually was reduced to the wilting point sometime in July, whereas the irrigated plot received water prior to reaching the wilting point. In one study (10) concerning the use of "excess" moisture, irrigations were made when approximately 70 per cent of the available soil moisture had been used, and no injurious effects were found on prunes or walnuts. Growth and yields of prunes were found to be affected as much by the lack of "readily available moisture" for a relatively short period in mid-summer as for a longer period late in the season (9). Also, fruit affected by lack of moisture during the fruit growing season remained small even with subsequent irrigations (9).

Growth of apples, according to Magness, Degman, and Furr (18) was not slowed down until soil moisture was near the permanent wilt-

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ing point. However, Magness, Regeimbal, and Degman (17) reported that carbohydrate synthesis in apple foliage was reduced under conditions of moisture shortage and that this reduction was correlated with reduced stomatal openings. Under these conditions there was a reduction in the starch present in storage tissues but an increase in the sugar content of plant juices.

Experiments conducted by Heinicke and Childers (6) showed that gradual drying of the soil was accompanied by an appreciable reduction in the rate of transpiration and of photosyntheses. Since the influence was noticeable first in transpiration, they reasoned that the early closing of the stomata, associated with a reduced water supply, conserved water to a greater extent than it reduced photosynthesis.

Schneider and Childers (23) found a marked reduction, 55 per cent, in apparent photosynthesis before wilting was evident, and a further reduction was associated with wilting. Also, wilted leaves were observed to require 2 to 7 days after watering to recover the original level of photosynthesis. The tests of Schneider and Childers began when the soil was at field capacity, and an increase in apparent photosynthesis was observed to be associated with a slight decrease in soil moisture below field capacity.

Anjou pear trees growing in a heavy clay soil were found by Aldrich and Work (1) to suffer from insufficient water when the soil moisture dropped below 50 to 80 per cent of the available soil moisture. They also found that the use of 30 to 40 per cent of the available soil moisture during the preceding year resulted in an increased amount of bloom. This increased bloom appears to agree with the findings of Schneider and Childers cited above. Lewis, Work, and Aldrich (16) summarized their pear irrigation experiments on heavy soils by recommending that the available soil moisture content be maintained above 50 per cent. This recommendation was based on the general findings that the growth rate of the fruit was closely related to the moisture content of the upper three feet of soil, and that the growth rate was reduced whenever the moisture content in this zone fell below 70 per cent of the available soil moisture.

The results for pears grown on heavy soils were comparable to those reported by Allmendinger, Kenworthy, and Overholser (2), who found a reduction in apparent photosynthesis when more than 80 per cent of the available soil moisture had been utilized. Trees that used 80 per cent of the available moisture did not show a reduction in apparent photosynthesis, but growth was reduced and the trees required less moisture than those trees using smaller amounts of the available moisture prior to watering.

Claypool (4) and Jones (13) reported experiments that further corroborated the results of others, showing a reduction in growth prior to reaching the wilting point. Claypool found fruit size was reduced as the available soil moisture was lowered to zero; Jones found that fruit size was correlated with moisture conditions when a constant leaf-fruit ratio was maintained.

Experimental Procedure

The soil used in these investigations was obtained from a grass sod cut in 1941 from a Palouse silt loam soil. At the beginning of the experiment each year the sod was moved into the greenhouse and, when sufficiently dry, passed through a soil grinder and a ¼-inch mesh screen. To prevent shrinkage the screened soil was mixed with sand and peat moss in volumetric proportions of 6–3–1 respectively.

The trees used were 3 to 4 foot, 1-year-old Winesap whips that had been selected for uniformity at the nursery in order to reduce variation. Before planting, each tree was washed free of adhering soil and placed in water for a short time to prevent drying. The excess moisture was then removed, the top cut back to 14 inches, and the tree weighed. After weighing the tree was planted in a 50-pound berry can, capacity approximately 1 cubic foot, using a uniform weight of soil. Trunk diameter measurements were taken after planting and tensiometers (15, 20, 21, 22) installed in each container. Two tensiometers were used for each tree in 1941 and only one in 1942.

After planting the required number of trees an additional group was washed, pruned and weighed as above. The tops were severed from the roots at the point of grafting, subjected to live steam for 3 minutes and dried at 100 degrees C. These trees were used to determine the ratio of roots to tops and per cent moisture at planting time.

The range of soil moisture between field capacity, as determined by a suction method (3), and wilting point, as determined by use of sunflowers, was divided into five equal parts; thus establishing five treatments. These treatments permitted the trees to use 20, 40, 60, 80, or 100 per cent of the available soil moisture prior to watering. When the allotted amount of the soil moisture had been used the tree was given sufficient water to bring the soil mass to field capacity without any runoff or gravitational water. Six trees were used in each treatment in 1941 and in 1942 nine trees were used for each treatment. The 1941 trees were grown from February 22 to May 15.

Daily tensiometer readings were taken after growth started and each tree watered as needed. At the close of the experiment each year the chlorophyll contents of the leaves were measured using a method employing a copper phaeophytin derivative of chlorophyll (15). After the chlorophyll determinations were made the tree was divided into leaves, shoots and roots subjected to live steam for 3 minutes and dried at 100 degrees C. All plant parts were weighed before and after drying. Leaf area calculations were based upon weight-area relationships established for the chlorophyll analyses. Trunk diameter and length of shoot growth were measured before dividing the tree.

Presentation of Data

The soil moisture range, cup tension in centimeters of mercury, rate of water utilization and application, and uniformity of trees at planting time is given in Table I for the five treatments for each year.

Although the same soil was used each year, the fresh sod in 1941 had a higher moisture content at field capacity than the year old sod in

TABLE I—SOIL MOISTURE RANGE, MERCURY TENSION, RATE OF WATER APPLICATION AND UTILIZATION, AND TREE UNIFORMITY AT PLANTING TIME

Determination	Year	Available Soil Moisture (Per Cent Used)				
		20	40	60	80	100
Soil moisture range (per cent)	1941 1942	37.0–31.0 33.1–28.7	37.0–25.0 33.1–24.3	37.0–19.0 33.1–19.9	37.0 13 0 33.1 15.5	37.0- 7.0 33.1 11.1
Mercury tension (cm)	1941 1942	2.6 4.3	6.8 7.7	18.4 17.6	41.5 42.0	* *
Amount of water applied per watering (ml)	1941 1942	1,200 1,060	2,400 2,120	3,600 3,180	4,800 4,240	6,000 5,300
Number of times watered	1941 1942	50.0 37.4	21.3 17.6	15.0 10.1	5.3 6.1	1.6 2.6
Total amount of water used (ml)	1941 1942	60,000 39,644	51,120 37,312	54,000 32,118	25,440 25,864	9,600 13,780
ry weight of trees when planted (g)	1941 1942	45.2 52.8	45.4 57.8	46.0 54.7	45.6 52 8	46 2 56.2
Trunk diameter of trees when planted (cm)	1941 1942	0.93 0.98	1.04 1.03	1.02 1.01	1.03 0.99	1 05 1.01

*Tensiometer construction would not record mercury tension at the wilting point. Wilting of leaves was used as an index of water utilization.

1942. This may have been due in part to the decomposition of organic matter after the sod was cut.

There was a pronounced difference in the frequency of watering and the amount of water used by the various treatments. The treatments using 20, 40 and 60 per cent of the available soil moisture received essentially the same amount of water during the growing period while considerably less water was required when 80 or 100 per cent of the available soil moisture was used. Although the trees were larger in 1942 at the time of planting, as shown in Table I, less water was used, and as will be shown later, less growth was made during the 1942 growing period. These features are believed to be due to the unbroken rest period at the time of planting.

The trees were rather uniform between treatments as shown in Table I. Analysis of variance failed to show any significant differences existing in the comparisons by treatment of the computed dry weight or trunk diameter at the time of planting.

At the close of the experiment there was a very marked difference in size of tree and amount of growth made by the different treatments. These differences are shown in Fig. 1 which presents photographs of one tree of each treatment that was selected on the basis of average trunk diameter increase occurring during the 1941 growing period. Measurements and calculations made on the growth, chlorophyll content, and leaf area, as influenced by the utilization of soil moisture, are presented in Table II.

Shoot growth and chlorophyll content per tree, as shown in Table II had somewhat similar trends in that both showed a marked reduction when at least 80 per cent or more of the available soil moisture was used, prior to the application of water. There was no significant reduction in shoot growth when the use of 80 per cent of the available soil

TABLE II—GROWTH, CHLOROPHYLL CONTENT AND LEAF AREA AS INFLUENCED BY THE UTILIZATION OF SOIL MOISTURE

	Year	Available Soil Moisture (Per Cent Used)					Mean Difference for Significance	
		20	40	60	80	100	5 Per Cent	1 Per Cent
Shoot Growth (cm)	1941	230.00	230.00	240.00	154.00	99.00	89.00	148.00
	1942	156.00	187.00	148.00	131.00	86.00	57.00	102.00
	Average	193.00	208.00	194.00	142.00	92.00	59.00	99.00
Chlorophyll content (mg/tree)	1941	265.42	281.62	262.96	163.52	88.76	117.20	194.38
	1942	241.07	262.53	222.32	174.31	101.09	62.65	103.91
	Average	253.24	272.08	242.64	168.92	94.92	59.10	98.02
Increase trunk diameter (cm)	1941	0.36	0.36	0.37	0.15	0.08	0.05	0.09
	1942	0.36	0.36	0.30	0.20	0.11	0.08	0.13
	Average	0.36	0.36	0.34	0.18	0.10	0.08	0.13
Chlorophyll content (mg/dm²)	1941	8.99	9.60	9.50	8.98	8.59	2.16	3.14
	1942	9.47	9.79	9.89	9.49	9.42	1.14	1.89
	Average	9.23	9.70	9.70	9.24	9.00	1.08	1.80
Total leaf area (dm²)	1941	29.32	29.51	28.71	17.44	10.46	12.66	29.99
	1942	25.68	26.89	22.51	18.68	10.72	7.50	12.43
	Average	27.50	28.20	25.61	18.06	10.59	6.80	11.80
Increase dry weight (g)	1941	85.30	95.60	97.10	49.10	28.50	39.70	65.80
	1942	80.30	89.70	68.70	49.50	23.60	22.50	37.40
	Average	82.60	92.60	82.90	49.30	26.00	21.10	35.00

moisture was compared to the use of 20 and 60 per cent. However, the shoot growth was significantly less than the treatment using only 40 per cent of the available soil moisture. When the trees were allowed to wilt, the shoot growth was significantly less than that produced when only 20, 40 or 60 per cent of the available soil moisture was used. These same relationships were true for the chlorophyll content per tree except that there was a significant reduction when more than 60 per cent of the available soil moisture was used prior to watering. This similarity in the amount of shoot growth and chlorophyll content per tree may be expected in that there was no significant differences in chlorophyll content per unit of leaf area.

The increase in trunk diameter for trees using 80 per cent of the available soil moisture was significantly less than for trees using 20,

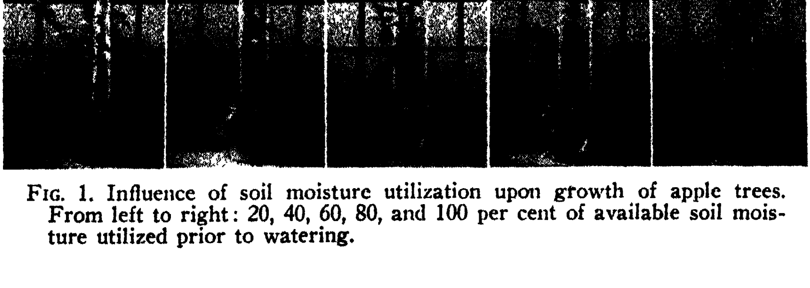

FIG. 1. Influence of soil moisture utilization upon growth of apple trees. From left to right: 20, 40, 60, 80, and 100 per cent of available soil moisture utilized prior to watering.

40 and 60 per cent. Trees using 100 per cent increased significantly less in trunk diameter than trees using 80 per cent of the available soil moisture. There was no significant change in trunk diameter increase when 20, 40 or 60 per cent of the available soil moisture was used. The same relationships shown for the increase in trunk diameter, as influenced by the utilization of soil moisture, also existed for measurements of the total leaf area per tree and the increase in dry weight per tree.

The slight influence of the utilzation of only 20 per cent as compared to the utilization of 40 per cent of the available soil moisture is interesting. There was a reduction in all measurements as shown in Table II when not more than 20 per cent of the available soil moisture was used prior to watering. This was apparently due to a lack of proper aeration of the soil.

Moisture content and dry weight of leaves, shoots roots, and the entire tree associated with the utilization of varying amounts of available soil moisture are shown in Fig. 2.

The moisture content of shoots and roots was slightly less when 20 per cent of the available soil moisture was used as compared to using 40 per cent (see Fig. 2). However, the reverse was true for the leaves, while there was no difference for the entire tree. The moisture content for the entire tree was significantly reduced by the utilization of the 100 per cent of the available soil moisture as compared to the utilization of 20 and 40 per cent. The shoots showed a significant reduction in moisture content when 100 per cent of the available soil moisture was used as compared to the use of 20, 40 or 60 per cent of the available soil moisture. The leaves showed a significantly higher moisture content when the soil moisture was maintained above 20 per cent as compared to those trees allowed to wilt prior to watering. As for the roots, no significant differences occurred in the average values. However, in 1942 the moisture content of the roots was significantly higher when only 20 or 40 per cent of the available soil moisture was

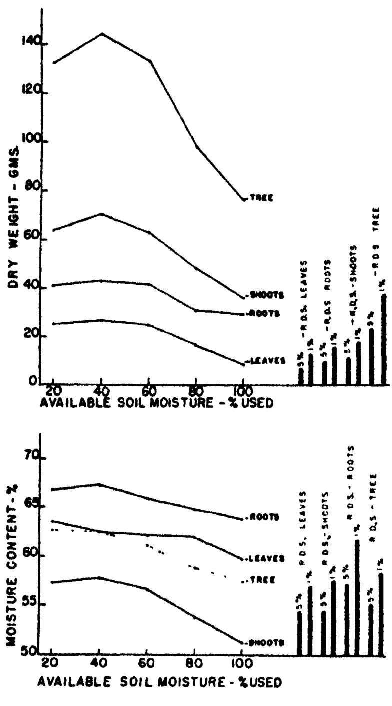

FIG. 2. Moisture content and dry weight of tree parts and of the entire tree as influenced by the utilization of soil moisture (R.D.S.—required difference for significance).

used as compared to the use of 100 per cent. The differences existing in the average values for the moisture content of the leaves, shoots, and for the entire tree were, in general, similar for both years.

The dry weight of leaves and shoots produced by the utilization of 100 per cent of the available soil moisture was significantly less than for any of the other treatments. Likewise, the dry weight produced by the use of 80 per cent of the available soil moisture was significantly less than for treatments using 20, 40 or 60 per cent. There were no differences in dry weight of leaves and shoots produced by the use of 20, 40 or 60 per cent of the available soil moisture.

There was no significant reduction in the dry weight of roots or for the entire tree produced by the utilization of 80 per cent of the available soil moisture. When 100 per cent of the available soil moisture was utilized the dry weight of roots and entire tree was reduced significantly. However, the dry weight production did not vary significantly by using 20, 40 or 60 per cent of the available soil moisture.

As was true for chlorophyll content, shoot growth, and total dry weight increase, the use of only 20 per cent of the available soil moisture caused a slight but insignificant reduction in the dry weight of all parts of the tree as compared with those trees using 40 per cent of the available soil moisture. This may be attributed to the lack of proper aeration of the soil when not more than 20 per cent of the available soil moisture was used. Should aeration be the sole factor, one could logically expect the roots to exhibit the greatest variation. However, the shoots showed the greatest reduction in dry weight which indicates that a lack of aeration did not inhibit root growth, but limited the absorption of nutrients essential for the production of dry matter.

The amount of chlorophyll and leaf area per unit gain in dry weight (Fig. 3), and ratios between dry weight of leaves, shoots and roots were calculated as an aid in the interpretation of the influence of soil moisture utilization.

The chlorophyll content and leaf area per unit of dry weight increase, as shown in Fig. 3, were smallest when 40 per cent of the available soil moisture was used prior to watering. This indicates that the chlorophyll and leaf area may be assumed to function

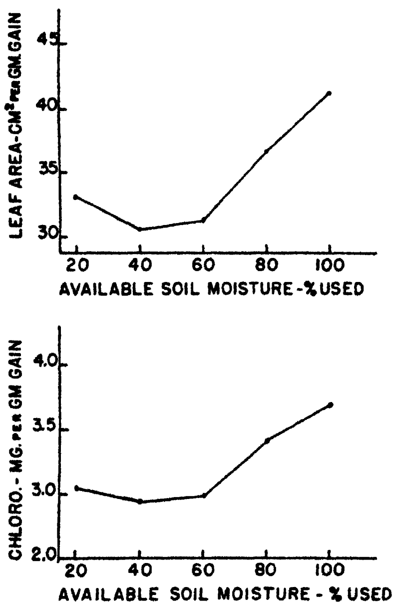

FIG. 3. Chlorophyll and leaf area per unit of gain in dry weight as related to the utilization of soil moisture.

most efficiently within this range of available soil moisture. The efficiency of the chlorophyll and leaf area were markedly reduced when 80 or 100 per cent of the available soil moisture caused a less marked reduction in the efficiency of the chlorophyll and leaf area.

The ratio of shoots to roots showed the least variation resulting from the use of varying amounts of available soil moisture, while the greatest variation occurred in the root-leaf ratios. These ratios show the dry weight of leaves to be more readily influenced than shoots or roots by the utilization of greater percentages of the available soil moisture. However, this influence does not appear very noticeable until 100 per cent of the available soil moisture is used prior to watering.

The correlation coefficients and regression equations found in correlation studies between the amount of water used, leaf area, chlorophyll content per tree, shoot growth, trunk diameter increase, and dry weight increase are presented in Table III. As is shown in this table

TABLE III—CORRELATION COEFFICIENTS AND REGRESSION EQUATIONS FOR VARIOUS CORRELATED FACTORS

Correlated Factors*		Correlation Coefficient	Regression Equation
x	y	r =	Ey =
Water used	Leaf area	0.896	0.527x + 4.17
Water used	Chlorophyll	0.850	4.70x + 48.1
Water used	Shoot growth	0.856	3.83x + 33.1
Water used	Trunk diameter increase	0.846	0.007x + 0.03
Water used	Dry weight increase	0.879	1.79x + 6.06
Leaf area	Chlorophyll	0.970	9.11x + 6.78
Leaf area	Shoot growth	0.920	7.00x + 8.81
Leaf area	Trunk diameter increase	0.912	0.013x − 0.017
Leaf area	Dry weight increase	0.954	3.30x − 5.99
Chlorophyll	Shoot growth	0.879	0.712x + 15.17
Chlorophyll	Trunk diameter increase	0.905	0.0014x − 0.23
Chlorophyll	Dry weight increase	0.946	0.35x − 5.93
Shoot growth	Trunk diameter increase	0.817	0.0015x + 0.022
Shoot growth	Dry weight increase	0.900	0.429x − 3.30
Trunk diameter increase	Dry weight increase	0.913	249.42x + 0.0

*Correlated factors were expressed in the following units: Water used—liters, leaf area—square decimeters, chlorophyll—milligrams per tree, shoot growth—centimeters per tree, trunk diameter increase—centimeters; and dry weight increase—grams, 75 values for each correlation.

the inter-relationships between water used, leaf area, chlorophyll content per tree, shoot growth, trunk diameter increase, and dry weight increase all have a correlation coefficient far above that required for significance at the 1 per cent level. Scattered diagrams of the loci for these correlations failed to show any grouping by years or by treatments. Therefore, both years and all treatments were grouped together for the calculation of the correlation coefficients and regression equations.

The regression equation for the correlation between trunk diameter increase and dry-weight increase is the only one that shows a zero point of origin. By analyzing these regression equations, the following conclusions may be made: initial chlorophyll development and growth is accomplished at the expense of the initial moisture available in the soil or in the tree; chlorophyll development and shoot growth precede leaf area development; trunk diameter increase and dry weight increase lags behind leaf area development; shoot growth initiates prior

to chlorophyll development; trunk diameter increase precedes shoot growth while dry weight increase lags behind shoot growth; and dry weight increase is simultaneous with trunk diameter increase.

Discussion

The results presented here agree fairly well with the results of experiments conducted by various other workers (1, 2, 4, 6, 8, 9, 13) in that apple trees show a marked reduction in growth prior to depleting all the available soil moisture. The claim of Hendrickson and Veihmeyer (8, 9, 10, 11, 12) that all the available soil moisture is readily usable is not supported by these studies. A question may be raised in regard to the accuracy in determining the moisture status in a volume of soil that would be occupied by the roots of several trees. Unquestionably, several samples for each depth reported would be essential for this determination. Since there is a normal but restricted cross-transfer of moisture within the tree (5, 19), if a certain unsampled soil area should contain available water, such moisture would be available to all parts of the tree. Such conditions may have existed at depths below those sampled by Hendrickson and Veihmeyer. Only a few roots would need to penetrate these depths in order to obtain the moisture.

Apparently, however, fruit tree growth is closely associated with the soil moisture available in the soil mass where the largest concentration of roots occur (1, 4, 13, 16). The experiments reporting such findings, however, were conducted on soils of finer textures than were used by Hendrickson and Veihmeyer.

Curves relating per cent of soil moisture to tension show that the increase in tension associated with drying of the soil is more gradual on soils having large sized particles than on soils having small sized particles. Thus the difference in tension, diffusion pressure deficit, or similar measurements, from field capacity to "near" the wilting point is relatively small on soils of large sized particles as compared to soils of small sized particles. This would indicate that in order to measure the response of fruit trees to gradual drying of the soil, or use of different amounts of the available water prior to irrigation, a more extensive and refined experiment would be needed on soils of large sized particles than on soils of small sized particles.

Stomatal activity has been assigned as being the principal factor in limiting photosynthesis during periods of drought (4, 6, 13, 17, 18, 23). The closing of the stomata first retards the rate of transpiration (6, 23), and then reduces the apparent photosynthesis. This reduction in apparent photosynthesis is persistent for a time even after moisture has been replaced (23). Apparently reduction in photosynthesis, associated with moisture deficiency, is not solely governed by the closing of the stomata, but also by some factor that requires a period of regeneration before a recovery in photosynthesis is effected. As observed in these studies, chlorophyll is reduced when the demands for soil moisture are excessive. Therefore, stomatal activity together with reduced chlorophyll content and certain other factors limit photosynthetic activity under conditions of drought.

Conclusions

Through greenhouse studies it was found that utilization of 80 per cent or more of the available soil moisture significantly reduced total chlorophyll per tree, shoot growth, trunk diameter increase, dry weight increase, and leaf area.

Chlorophyll per unit of leaf area was not decreased significantly by using 80 per cent or more of the available soil moisture.

Permitting apple trees to use only 20 per cent of the available soil moisture resulted in an insignificant decrease in chlorophyll per unit of leaf area, total chlorophyll per tree, shoot growth, trunk diameter increase, dry weight increase, leaf area, and moisture content of shoots and roots.

The moisture content of shoots, leaves, and the entire tree was significantly reduced by permitting the trees to wilt prior to watering.

The efficiency in production of dry matter by a unit of chlorophyll or leaf area was highest when the trees were permitted to use 40 per cent of the available soil moisture prior to watering.

Correlations of high significance were found to exist between amount of water used, leaf area, chlorophyll content per tree, shoot growth, trunk diameter increase, and dry weight increase.

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Factors Contributing to the Growth of Newly Transplanted Tung Trees

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TRANSPLANTED tung trees characteristically exhibit two sigmoid growth curves during the first year in the orchard rather than a single one as normally expected for most plants. This abnormality is caused by a drop in the growth rate following the first surge of growth; the severity and duration of the drop are of considerable practical importance because trees that suffer a marked and prolonged drop in growth rate in the spring fail to make satisfactory total linear growth by the end of the growing season. Spring droughts, which frequently occur in southern Georgia and northwestern Florida, are thought to contribute to the drop in growth rate, but it seems likely that factors other than droughts are involved. Proper cultivation has been the greatest factor in minimizing it (1, 3, 4). In order to devise further means of reducing the objectionable drop in growth rate it is necessary to understand more completely the factors involved.

MATERIALS AND METHODS

In 1948, tung trees were planted in two separate experiments designed to determine: (a) whether established trees with roots intact exhibit a drop in growth rate similar to transplanted trees; (b) whether root systems are adequate at the time that the drop in growth rate occurs; (c) whether limiting top growth has any major effect on root growth; (d) whether the drop in growth rate can be eliminated or modified by better care of the trees during transplanting; and (e) whether exhaustion of stored food reserves affects the drop in growth rate.

On February 16 an experiment was set up near Thomasville, Georgia, on Red Bay fine sandy loam to compare the rate of growth of 24 transplanted 2-year-old seedling nursery trees pruned back to 18-inch trunks with that of 24 similar trees pruned back but left in the nursery with roots undisturbed. The transplanted trees were dug with a maximum amount of fibrous roots intact and with such care that the roots were not exposed to the air for more than a few seconds. Each plot consisted of two trees planted 24 to 30 inches apart and each treatment was replicated 12 times. The trees were allowed to develop a vase form and linear growth measurements were taken from time to time. Each tree received ½ pound of 3-8-6 fertilizer on April 19, and ¼ pound of zinc sulphate. The trees were cultivated frequently to eliminate any effect of weed growth.

On February 20, at Cairo, Georgia, 96 2-year-old seedling nursery trees were cut off at 18 inches, dug up, and exposed to the air for approximately 1 hour, after which one lot of 48 trees were heeled in; the trees of the other lot were exposed to the direct rays of the sun for 5½ hours before being heeled in. All trees were replanted on March 2 on Norfolk fine sandy loam soil. Thereafter one-half of each lot was

pruned by rubbing off all developing buds every few days; the other half of each lot was unpruned. The trees were cultivated frequently to eliminate any effect of weed growth. Each tree was fertilized with 1/4 pound of 3-8-6 fertilizer on April 29 and 1/2 pound of 4-8-6 fertilizer and 1/4 pound of zinc sulphate on June 8. More than the usual amount of rainfall fell in the spring of 1948, but periods of dry, hot weather occurred during May and June (Fig. 1). On May 26 the trees were irrigated until the soil was saturated to a depth of at least 2 feet. Two days later a moderate rainfall added further moisture.

Linear shoot growth measurements were recorded from time to time and daily rates of growth were calculated. One-third of the trees were dug April 10, one-third May 7, and the remainder June 28, for root growth determinations from which top/root ratios were calculated. In measuring root growth, roots arising from callus tissue formed at the severed ends of large roots were recorded separately from fibrous roots arising at other points. In order to make further observations, trees removed and stripped of top and root growth on April 10 and May 7 were immediately replanted in the same place from which they had been dug.

The trees were arranged in a split plot design in which dates of digging were the main plot treatments, set up in four replications, eight trees per plot. The four combinations of exposure of roots with pruning after planting formed the sub-plot treatments, differences between which are determined with maximum precision. Each sub-plot consisted of two trees.

Results

The trees stripped of roots and shoot growth on April 10 when the daily rate of growth was 2.5 centimeters and on the increase and those similarly treated on May 7 after the daily rate of growth had passed the peak and had dropped to 1.9 centimeters, produced, when replanted, growth curves paralleling previous growth responses (Fig. 1). The

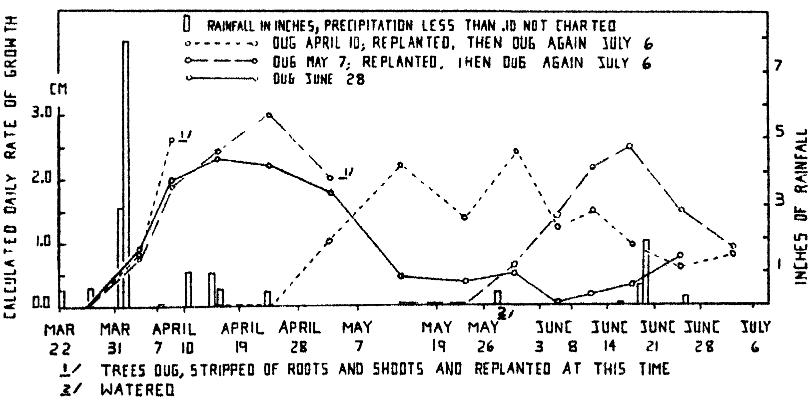

Fig. 1. Effect of digging and replanting on calculated daily rate of shoot growth of 2-year-old seedling tung trees transplanted March 2, 1948.

twice-planted trees reached high maximum rates of growth during a period when check trees not replanted were growing very slowly. During the period June 8 to 14, when the check trees planted March 2 were growing at a rate of 0.05 centimeters per day, the trees stripped of roots and top growth April 10 were growing at the rate of 1.21 centimeters per day, and those similarly stripped and replanted May 7 at the rate of 2.15 centimeters per day.

Response to irrigation on May 26 depended on the condition of the trees and type of growth. Slow growing trees with considerable top growth responded slightly to the application of water. Trees undergoing the first surge of top growth, therefore having little leaf surface, were not influenced by application of water. Trees actively growing and having produced considerable top growth readily responded to watering.

Double sigmoid growth curves were not restricted to transplanted trees. Trees with all the food reserves and absorptive ability of established 2-year-old roots suffered a drop in growth rate (Table I). Transplanted trees, as well as trees with undisturbed roots, reached a high rate of growth by April 15, dropped to a minimum by June 7, and were recovering by June 29. The daily rates of growth for the periods ending May 19, June 7, and June 29, were respectively, 1.23, 0.21, and 0.81 centimeters for transplanted trees, and 7.34, 5.25, and 16.23 centimeters for trees with undisturbed roots. The average growth rate in early June was approximately 17 per cent of the previous maximum growth rate in the case of transplanted trees and approximately 72 per cent in the case of trees with undisturbed roots. The differences in growth rate between transplanted trees and undisturbed trees during these three periods, expressed as percentage of the previous maximum growth rate, attained statistical significance beyond the .001 level of probability. Trees with undisturbed roots produced more terminal growth than the transplanted trees, the difference by April 5 attaining a significance beyond the .01 level of probability, and differences at later dates a significance beyond the .001 level.

TABLE I—EFFECT OF TRANSPLANTING ON TOTAL LINEAR TOP GROWTH OF TWO-YEAR-OLD TUNG TREES TRAINED TO VASE FORM

Date of Measurement and Final Date for Each Growth Period	Trees Not Transplanted		Trees Transplanted	
	Total Linear Growth (Cm)	Calculated Daily Rate of Growth (Cm)	Total Linear Growth (Cm)	Calculated Daily Rate of Growth (Cm)
Apr 5	25 7	— —	21.6	—
Apr 15	99.7	7 40	59 7	3.81
May 19	349 3	7.34	101 5	1.23
Jun 7	449.0	5 25	105 4	0.21
Jun 29	806 0	16 23	123 3	0.81

In the experiment having to do with exposure of the roots to sun and with disbudding subsequent to planting, it was found that the exposure did not significantly affect top or root growth. Hence only data on pruning and date of digging will be presented here.

During the period prior to April 10, non-disbudded trees produced

on the average 1.64 grams of top growth; between April 11 and May 7, 24.57 grams; and from May 8 to June 28, 25.34 grams. The percentages of the total top growth for the three successive periods were 3.2, 47.7, and 49.1 respectively. Corresponding root weights of non-disbudded trees during the three successive periods, were .21 grams, 1.28 grams, and 8.13 grams, and the percentages of the total root growth for the three periods were 2.2, 13.3, and 84.5.

During the period prior to April 10, non-disbudded trees produced on the average 0.21 grams of fibrous roots, from April 11 to May 7, 1.19 grams and from May 8 to June 28, 2.06 grams. The percentages of the total fibrous roots for the three successive periods were 6.1, 34.4, and 59.5, respectively. Corresponding data for trees continually disbudded were 0.05 grams and 0.23 grams, respectively, during the first and second periods; during the third period there was an apparent loss, no doubt due to sampling error. The percentages of total fibrous roots for the first and second periods were 17.9 and 82.1, respectively.

None of the trees dug April 10 had formed callus tissue at the severed ends of the large roots. Fourteen out of the 16 trees with normal top growth had callus tissue formation by May 7. Of these 14 trees, four had a few roots developing from the callus tissue. All trees dug June 28 had large callus growths and numerous roots developing from the callus regions.

During the period prior to April 10 non-disbudded trees produced on the average 0.00 grams of callus roots, between April 11 and May 7, 0.09 grams and between May 8 and June 28, 6.07 grams. The percentages of total callus roots for the three successive periods were 0.00, 1.5, and 98.5 respectively. Corresponding data for trees continually disbudded were 0.00 grams, 0.0005 grams, and 0.32 grams, respectively; 99.9 per cent of the total callus root growth occurred between May 8 and June 28.

Roots from callus tissue differed greatly from typical fibrous roots, being much thicker. The fibrous root system did not assume the functions of main roots; instead there was regeneration of the main root system from roots arising from callus tissue formed at the severed ends of the original roots. In general, the amount or weight of roots from callus tissue was correlated with the extent to which the root system spread beyond the area bounded by the original root system as transplanted. Roots entering the deeper layers of soil invariably came from callus tissue; the longest roots arising from callus tissue were not, on the average, more than 6½ inches.

Average top/root ratios for all trees dug April 10, May 7, and June 28 were 6.31, 14.72, and 5.06, respectively. Between April 11 and May 8, the increase in top growth was 19.2 times the increase in root growth. Between May 8 and June 28 top growth increase was only 3.1 times the root growth increase.

Differences in fibrous, callus and total roots due to disbudding and the corresponding interactions of period with disbudding all attain statistical significance at or near the .001 level. Over-all differences between periods attain statistical significance only in the case of callus roots (Table II).

TABLE II—EFFECT OF DISBUDDING ON TOP AND ROOT GROWTH OF TRANSPLANTED TWO-YEAR-OLD NURSERY TUNG TREES, DUG APRIL 10, MAY 7 AND JUNE 28, 1948.

Criterion	Growth During Successive Periods						
	Prior to Apr 10		Apr 11 to May 7		May 8 to Jun 28		Season
	Weight (Gms)	Proportion of Total (Per Cent)	Weight (Gms)	Proportion of Total (Per Cent)	Weight (Gms)	Proportion of Total (Per Cent)	Total Weight (Gms)
Top growth per tree							
Disbudded	0.00	—	0.00	—	0.00	—	0.00
Not disbudded	1.64	3.2	24.57	47.7	25.34	49.1	51.55
Average	0.82	3.2	12.28	47.7	12.68	49.1	25.78
Fibrous roots							
Disbudded	0.05	17.9	0.23	82.1	†	†	0.28
Not disbudded	0.21	6.1	1.19	34.4	2.06	59.5	3.46
Average	0.13	7.0	0.71	38.4	1.01	54.6	1.85
Callus roots							
Disbudded	0.00	0.0	0.00*	0.0	0.32	100.0	0.32
Not disbudded	0.00	0.0	0.09	1.5	6.07	98.5	6.16
Average	0.00	0.0	0.05	1.5	3.19	98.5	3.24
Total roots							
Disbudded	0.05	8.9	0.23	41.1	0.28	50.0	0.56
Not disbudded	0.21	2.2	1.28	13.3	8.13	84.5	9.62
Average	0.13	2.6	0.76	14.9	4.20	82.5	5.09
Top/root ratio of non-disbudded trees	7.81		19.2		3.1		

*The 16 trees actually had a few callus roots, averaging 0005 grams per tree.
†The weight of fibrous roots on the trees dug June 28 was slightly less than that for trees dug May 7.
Differences in fibrous, callus, and total roots due to disbudding and the corresponding interactions of period with disbudding all attain statistical significance at or near the .001 level.
Over-all differences between periods attain statistical significance only in the case of callus roots.

DISCUSSION

It has been repeatedly observed that newly transplanted tung trees begin the growing season with a relatively high rate of top growth. This high rate of growth is of short duration, followed by a decided decrease in growth rate often extending over a considerable number of days. It has been suggested that a depletion of initial reserves, moisture relations, and adverse top/root ratios may be factors causing this early spring decrease in growth rate.

It is not probable that the period of slow growth rate is caused by exhaustion of food reserves; if this were the case, trees steadily declining in growth rate would not resume active growth and parallel their previous growth curves when replanted after being stripped of root and top growth. It is also evident that the depression in growth may be to a considerable extent independent of drought and other climatic factors. Replanted trees were accelerating in growth rate at the same time and under the same environmental conditions under which growth was decreasing in the check trees which were not replanted. The response of the same trees to irrigation, as previously described, was apparently conditioned to a major extent, by internal factors.

The data on relation of top growth to root growth show that growth of roots was greatly retarded, even in the early stages, by disbudding the trees. If no top growth is made, more of the stored reserves should be available for root production; but it is clear that they are not effectively utilized in the absence of top growth. The data for the same

experiment show that the transplanted trees tend to make top growth first and then root growth. Between April 11 and May 7 the increase in top growth of nondisbudded trees greatly exceeded that of the roots, as is indicated by the top/root ratio of 19.2. This is true, but to a much lesser extent, for growth between May 8 and June 28 when the top/root ratio was 3.1.

Root growth is certainly dependent on organic foods synthesized in the leaves, and may also be dependent on other substances such as enzymes or hormones. On the other hand Went (5) has presented evidence to show that top growth in the tomato is greatly stimulated by a substance other than water and nutrients, which is produced in a relatively limited but well aerated portion of the root system. This suggests that substances in the nature of hormones may play an important role in controlling relative growth of roots and tops.

At the same time it is obvious that under field conditions moisture may be the all-important factor controlling top growth. Miller (2) reviews several experiments conducted between 1898 and 1930, which show rather consistently that in plants like corn and small grains relatively large tops and small root systems tend to develop in moist soils, while relatively small tops and large root systems tend to develop in dry soils. Apparently a moisture deficit checks growth of tops more than growth of roots. It is believed that both unfavorable top/root ratios and adverse moisture conditions may contribute to the check in top growth, and that these are the most important factors.

Summary

In an experiment with 2-year-old seedling tung trees it was found that both transplanted and non-transplanted trees began the growing season with a relatively high rate of growth, which was of short duration and was followed by a decided decrease in growth rate extending over a number of days.

Exposure of the roots to direct rays of the sun for 5½ hours had no significant effect on the severity or duration of the check in growth.

Trees dug and stripped of root and shoot growth during the drop in growth rate resumed active top growth upon replanting, at a time when check trees not replanted were growing very slowly. This indicates that the drop was independent of food reserves in the trees. To a certain extent it was also independent of the weather, since growth rate for one lot of trees was increasing at exactly the same time and under the same environmental conditions that growth in another lot was decreasing.

The data show that transplanted trees tend to make top growth first and then root growth.

Preventing top growth very greatly reduced the production of roots, and there appeared to be alternate cycles of top and root growth. It is suggested that the roots may supply substances essential for top growth, other than water and nutrients, and that roots require substances other than organic foods produced in the tops.

However, under field conditions soil moisture is obviously often the all-important factor controlling top growth.

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Wheels of Nutrition — A Method of Demonstrating Nutrient-Element Balance[1]

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NUTRIENT-ELEMENT balance for plants has been discussed for many years by research workers, instructors, extension specialists and growers. The earlier concepts of this balance involved only a few of the essential nutrient-elements. However, a more recent concept (2) maintains that all of the nutrient-elements essential for plant growth must be in proper balance or relationship with one another. Once one has a mental picture of this relationship the concept of nutrient-element balance is clear and understandable. However, students, growers or others who have not given much thought to the concept have difficulty in developing a mental picture that would enable them to visualize a balanced condition between the various nutrient-elements required by plants.

This difficulty may be largely the result of not having a means of expressing the balanced condition that is being constantly referred to, and which, in a large measure, still remains a theory. Plant analyses have been a very useful aid in demonstrating nutrient-element balance. Attempting, however, to visualize a balanced condition existing between absolute values of plant composition, such as 2.11 per cent nitrogen, 0.25 per cent phosphorus, 1.34 per cent potassium, 0.68 per cent magnesium, 1.12 per cent calcium, 120 ppm of manganese, 30 ppm of boron, and so on, is difficult because of the wide differences between such values. Students, growers, and other groups have listened to lectures and talks that attempted to familiarize them with such values, but standards have not been established so that they may have a constant reference point for comparison.

Various methods have been employed to depict visibly this balanced condition that is necessary for optimum plant growth. The usual graphs readily show by correleation the relationships that may exist between two elements. The use of triangular coordinates increases the discussion to three elements. The use of a "barrel-stave" technique as a visual aid enables one to picture readily the basic features of balance but mainly emphasizes the idea of limiting factors in that the barrel cannot be filled above the shortest stave. This leaves the longer staves as an extravagant use of nutrient-elements but does not bring in the concepts that a "toxicity" of one nutrient-element may be reflected in a "deficiency" of another. Also, with the "barrel-stave" technique, it is difficult to show diagramatically all of the elements in one picture.

Recently, the author has made several attempts in classrooms and at grower meetings to explain the concept of nutrient-element balance, interrelationships between nutrient-elements, and the influence that various cultural practices have on this balance. Students listening to

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such lectures were unable to grasp the meaning and growers showed little interest in the earlier lectures. This failure was largely because of the usual method of graphs, correlations, and other means of showing the relationships between two or three elements were used. Finally a method was developed as a visual aid that would enable one to compare all nutrient-elements, or as many as desired, in relation to each other as affected by two treatments, or a series of treatments with a standard treatment.

Analogies

A few analogies should be made so that the method may be more clearly understood. These are made by using a diagram of a wagon that is pulled by a tractor. The tractor is considered to represent capital while the various parts of the wagon may be considered as follows: the bed as production, the end-gate chain as spraying, and the reach as pruning. The wheels are the main part and are considered to be wheels of nutrition which are made up of spokes that represent the various nutrient-elements.

The object of striving for a nutrient-element balance is to enable the tractor or capital to pull a larger load with less work. This is accomplished by making all spokes of equal length; thus bringing them all into balance. The size of wheel also affects the capacity or production-load for a given size tractor or capital. Thus the capital is able to pull a larger production-load with larger wheels and the size of wheel is described as intensity of nutrient-element balance.

However, as with any vehicle, if the wheels are too large the safety factor is reduced. As this safety factor is reduced, there is a greater likelihood of "wrecks". In an orchard, these "wrecks" may be associated with serious outbreaks of insects or diseases, reduced quality, or a number of factors that may reduce marketable fruit of good quality. The optimum size for the wheel of nutrition is established, largely, by the weather or climate involved in the production area. Such features as soil, rainfall, light, length of day, temperatures, and so on may readily induce a change in the optimum values.

With these analogies, it is apparent that in order not to over-work the tractor or capital, the wheel of nutrition should be made up of nutrient-element spokes that are of the same and of optimum length. There is a likelihood of a reduction in yield, particularly marketable yield, if some spokes are too short or too long. This reduction means that the producer is not taking full advantage of the weather and is requiring excess capital per unit of production.

Ranges in Plant Composition

Leaf or plant analyses have shown that any one nutrient-element may vary considerably. In general the amount present in the material analyzed may vary from a very low value to a very high value. At very low values, visible deficiency symptoms are often present while at very high values visible symptoms of excess often occur, or as with some elements, a visible deficiency symptom develops for another element. Somewhere between these two extremes is found the value for opti-

mum growth, and/or production. This optimum value doubtlessly is not a constant for all years, varieties, species, or climates and may vary as a result of numerous factors.

Somewhere between the values for optimum growth, and the value where deficiency symptoms may occur, there is a range in plant composition where the plant responds markedly to nutrient-element applications. This range has been termed as "hidden hunger", or "hidden deficiency". Likewise, there is a range in composition somewhere between the optimum values and the values where visible excess symptoms may occur at which additions of a nutrient-element value results in a very marked reduction in plant growth and/or production. Such a range, in keeping with other terms, may be called "hidden excess" or "approaching excess".

Plant analyses have shown that optimum growth and production may occur when the analysis for any one nutrient-element varies considerably. Thus there appears to be a range of values in plant composition at which optimum growth, visible deficiency or excess symptoms, and "hidden deficiency" or excess may occur. These ranges in plant composition may be compared to a traffic signal light. The visible deficiency or excess range may be considered as the red or danger signal, the "hidden" deficiency or excess range may be considered as the caution signal, while the range for optimum growth may be considered as the green or go-ahead signal.

Such a color scheme has been used in a "nutrient-element balance chart" (1). This chart (Fig. 1) has a black center to represent the hub of the wheel and is surrounded by five concentric bands to represent the ranges in plant composition mentioned above. These bands are arranged from the black center outward as follows: The first band is colored red to represent the range of deficiency; the second band is amber to represent the range of "hidden" deficiency; the third band is green to represent the optimum range; the fourth band is amber to represent the range of "approaching" excess; and the fifth band is red to represent the excess range.

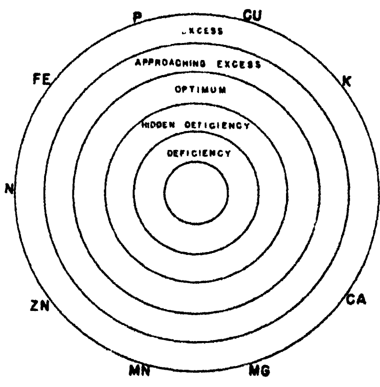

FIG. 1. Diagram of a chart showing the various concentric bands representative of the various ranges in composition.

The various nutrient-elements are located at regular intervals around the outer edge of the chart. There is no systematic arrangement of the elements except that the "major" elements are alternated with the "minor" elements. The 10 elements used in Fig. 2 represent the nutrient-elements commonly available as commercial fertilizers. However, as many elements as desired may be included.

The amount of the nutrient-element present in the plant material

FIG. 2. Circular plywood hub showing imbedded catches for holding spokes in place. This disc used on plywood chart shown in Fig. 3.

analyzed is expressed by drawing a line from the center of the circles toward the outer rim. Thus the center of the circles is the zero value for all elements and the line is drawn outward toward the element considered. The middle of the green band is considered as optimum and is assigned a value of 100 for each element. Therefore, instead of leaf analysis values being compared, which may range from 4.0 per cent to as low as 10 ppm or less, each standard or optimum value is assigned an index number of 100, and the analysis associated with other treatments are then compared to this standard.

This means that the lines drawn on the chart are the spokes in the wheel of nutrition that is associated with leaf analysis of a treatment in relation to a standard treatment or optimum values. The chart, therefore, shows the relative nutrient-element balance of a treatment in relation to the best or standard treatment, or the relative nutrient-element balance of a plant, field, or orchard in relation to the optimum values that have been selected as a basis of comparison. The length of the lines or spokes is determined by calculating the per cent variation from standard or optimum values.

The use of this chart, where absolute values are converted into percentage relationships to standard or optimum values, has an additional advantage, in that the results of leaf analysis may be expressed in terms of the element, as an oxide of the element, milli-equivalents of the element, or in any other manner preferred. Regardless of the method used in reporting actual analyses the chart or wheel of nutrition will show the same general relationships.

Statistically significant differences in the leaf composition as associated with different treatments may be calculated by means of the usual methods. A rough estimate of this significant differences may be made by requiring a 10 per cent variation in composition for significance. This means that a variation of approximately one-half the width of any one of the five bands on the chart would be significantly different from the accepted or adopted standard or optimum. Using this index, a nutrient-element may be considered as being significantly out of balance if the line representing it fails to reach or extends beyond the band representing the optimum range.

Demonstrating Nutrient-Element Balance

The leaf composition associated with various cultural treatments has been used in grower meetings and class lectures. The equipment used for such lectures is made of wood. A simple tripod is used for supporting a piece of ½-inch plywood on which are painted the various colored bands previously described. The 4-foot square of plywood is hinged, for convenience in carrying, to fold into four pieces in a manner similar to a paper napkin. A hole is drilled through the center and a bolt is inserted. Over this bolt is placed a circular piece of ½-inch plywood with a diameter of 7 inches which makes the black center for the hub of the wheel. At regular intervals, every 36 degrees, the catch part of a No. 5 roller cabinet door catch is imbedded near the edge of the circular piece of plywood. These catches are used for holding the spokes and makes a rapid means of changing the spokes or pieces of wood that represent the various elements (Fig. 2).

The spokes that represent the amount of a nutrient-element found in the leaf analysis are made from a piece of 1-inch half-round moulding that is planed to a ¼ inch thickness. The curved edges of the half-

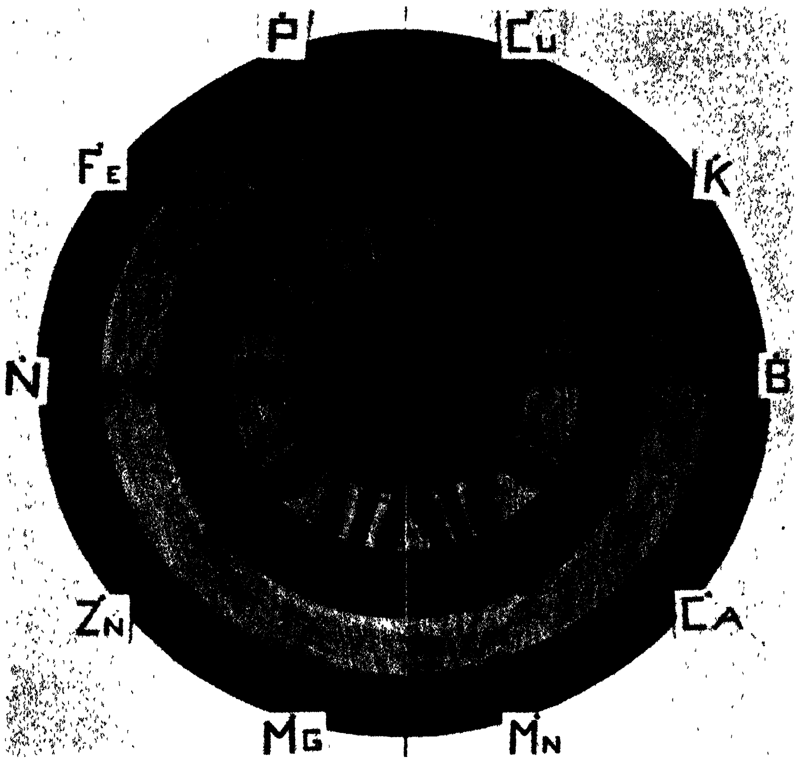

Fig. 3. Plywood chart showing the nutrient-elements and a nutrition wheel of optimum balance in place.

round moulding make a snug fit in the imbedded catch and hold the spoke snugly against the center disc (see Fig. 2). The spokes are placed on the center disc so that they extend 2 inches in from the outer edge of the disc. The dimensions of the large colored chart are such that 1 per cent variation from the standard corresponds to a similar change of ⅛ inch in the length of the spoke.

A bolt is inserted through the large chart to one side of the center of the inner circle and fits into a hole on the back of the center disc. This bolt locks the disc in position to prevent the wheel from turning. The symbols for the various elements are placed at 36 degree intervals around the outer edge of the outer red circle. These are made on white cards and placed on the chart by use of thumb tacks (Fig. 3).

After the wooden strips used for spokes have been cut to the proper length the outer surface is painted black. Each spoke is labeled on the reverse side with a gummed label, having a code corresponding to the lecture cards so that it may be properly identified. By placing small labels on the outer edge of the center disc the spokes may be quickly arranged in position and disc placed on the chart with no labels showing.

The various spokes are kept in their proper order by using a length of 36-inch denim cloth. Six inches were folded up on one side and sewed every 3 inches. This forms pockets into which five spokes can be placed (Fig. 4). A gummed label on the pocket identifies the set of

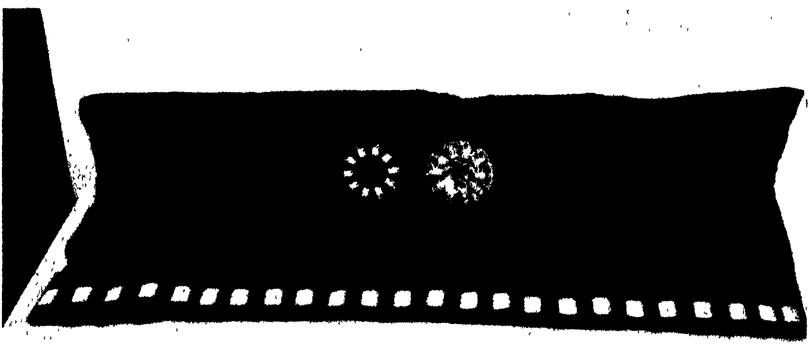

FIG. 4. The length of denim cloth with compartments for holding the spokes and keeping them in proper order.

spokes with the lecture cards. After the spokes are inserted into the pockets, the cloth is then rolled up and tied for convenience in carrying. During the lectures the cloth is unrolled and placed on a table and the spokes used as needed.

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Effects of Fertilizers Applied to Cover Crops on Cover Crop Yield, on Tung Trees, and on the Yield and Oil Content of Tung Fruit

By Ralph T. Brown and George F. Potter, *U. S. Department of Agriculture, Bogalusa, La.*

In the fall of 1944 an experiment was inaugurated in a 6-year-old seedling tung orchard on Irvington fine sandy loam soil near Irvington, Alabama, to determine what effect applications of nitrogen, potassium, dolomitic limestone, and manganese sulfate to the cover crop would have on the production of green manure and also on the production, composition, and maturity of the tung fruit[1].

The trees, which were planted 25 feet apart each way, were arranged in 32 plots of two trees each, the individual plots being separated by appropriate guard rows. From 1944 to 1946, lupine was seeded annually in September at the rate of 50 pounds per acre. The experiment was of factorial design with two levels each of nitrogen, potassium, manganese, and dolomite. The low level of each element was that available from the soil, including in the case of nitrogen that fixed by the lupine and volunteer legumes. The high level of each element consisted of the low level plus the following respective supplementary applications per acre: nitrogen, 24 pounds of N, as ammonium nitrate; potassium, 24 pounds of K_2O, as muriate of potash; manganese, 140 pounds of 65 per cent manganese sulfate; and dolomite, 500 pounds of a ground limestone containing 43 per cent magnesium carbonate. All plots received a basic application of 240 pounds per acre of 20 per cent superphosphate. All soil amendments were broadcast from tree row to tree row.

The 16 treatments, resulting from the combinations of four factors each at two levels, were randomized within each of two replications. In this design one-half of all plots received the low level of nitrogen and the other half the high level, both groups receiving comparable amounts of potassium, dolomitic limestone, and manganese sulfate. Differences between these groups reliably reflect the response to nitrogen, and by breaking the experiment down into smaller groups of treatments, interrelations of nitrogen with other fertilizers may be studied. The effects of potassium, dolimitic limestone, and manganese may be analyzed by similar procedures.

Cover crop yields were determined in May of each year, and were adjusted to a dry-weight basis by means of samples collected at the time of weighing the green crop. The yield of tung in any given year is determined largely by the number of blossom buds formed during the previous summer. Accordingly, the fertilizers applied in the fall of 1944 and lupine turned under in the spring of 1945 could not affect yield until 1946. Tung yield records were therefore taken in 1946, 1947, and 1948; the yield weights were adjusted to a 15 per cent moisture basis by means of samples of about 20 pounds of fruit taken from each plot

[1]This experiment was set up by the late George M. Bahrt, and was conducted by him until his death April 10, 1947.

at the time of harvest. Composition of the fruit may be affected by fertilizers applied the same season. The oil content of the fruit of each plot was determined in 1945 and in 1947 in accordance with the methods of sampling and analysis described by Potter *et al* (2). Observations on leaf scorch, leaf drop, and fruit maturity were made in November 1947.

Results and Conclusions

Cover Crop Yields:—Under the conditions of this experiment, of the four fertilizer materials applied to the cover crop supplemental to phosphorus, only potassium has consistently increased the yield of lupine for 1945, 1946, and 1947 (Table I). The average yield per acre per year for this period for those plots that received potassium was 1.61 tons greater than for those plots receiving no potassium, an 87 per cent gain in yield, statistically significant at the .001 level.

TABLE I—Effect of Potassium on Yield of Lupine in Tons Per Acre (Dry Weight—Irvington, Alabama 1945 to 1947)

Application K_2O per Acre (Pounds)	1945 (Tons)	1946 (Tons)	1947 (Tons)	Average 1945 to 1947 (Tons)
0	2.66	2.39	0.53	1 86
24	4.08	5.23	1.10	3 47
Gain by application	1 42	2.84	0.57	1 61

All differences are statistically significant at the .001 level

Yield and Composition of Tung Fruit:—Potassium very significantly increased both yield and oil content of fruit (Table II). The average increase in yield per tree per year for the 3-year period was 13.6 pounds and the increase in average oil content of fruit of the 1945 and 1947 crops was 2.2 in percentage value; both effects attain high statistical significance. Although dolomite had no significant effect upon the yield of cover crop, it decreased the yield of the tung trees by 8.4 pounds, a difference significant at the .05 level, and the average oil content by 0.8 in percentage value, which was not significant. Statistical analysis of the data showed that, contrary to the general experience, nitrogen did not improve yields or increase oil content. The failure to respond to the

TABLE II—Effect of Potassium and Dolomite Applied to Lupine Cover Crop, on Yield and Oil Content of Tung Fruit (Irvington, Alabama, 1946 to 1948)

Application Per Acre (Pounds)		Fruit Per Tree (Pounds)				Oil Content of Tung Fruits (Per Cent)		
Dolomite	K_2O	1946	1947	1948	Average 1946 to 1948	1945	1947	Average 1945 and 1947
0	0	8 3	16.4	19.9	14.9	17.6	17.1	17.4
500	0	6.7	10.0	11.2	9.3	16.6	15.6	16.1
0	24.0	21.9	36.8	35.0	31.2	17.5	20.8	19 1
500	24.0	13.5	23.6	23.3	20.1	18.1	19.5	18.8
Least difference significant at	0.05	3.4	7.3	9.3	8.2	1.4	1.7	1.3
	0.01	4.7	10.2	12.9	11.4	1.9	2.4	1.9
	0.001	6.4	14.0	16.6	15.8	2.7	3.3	2.6

nitrogen and the considerable increase in yield effected by potassium may be attributed to a serious potassium deficiency prevailing in this orchard.

Fruit Maturity:—On November 17, 1947, the trees in each plot were rated with respect to maturity of fruit on a scale ranging from 1.00, representing a tree from which no fruit had dropped, to 5.00, representing a tree from which three-quarters to all of the fruits had dropped. Average ratings per plot were calculated and the plot readings have been analyzed statistically. The application of nitrogen alone very significantly retarded the maturity of fruit; whereas the application of potassium, either alone or with nitrogen, hastened maturity of fruit (Table III). Practically 100 per cent of the fruit in plots that received (a) potassium or (b) nitrogen and potassium had dropped at the time of rating. These results are very similar to those reported in other experiments (1).

TABLE III—EFFECT OF NITROGEN, POTASSIUM, AND DOLOMITE APPLIED TO LUPINE COVER CROP, ON FRUIT MATURITY, INCIDENCE OF LEAF SCORCH, AND LEAF DROP OF TUNG (IRVINGTON, ALABAMA, NOVEMBER 17, 1947)

Application Per Acre (Pounds)			Average Score (Rating)			
N	K_2O	Dolomite	Fruit Maturity*		Leaf Scorch**	Leaf Drop†
0	0	0	3.74		1 75	2.38
24	0	0	2.18		2 38	2 50
0	24	0	4 88		1.00	1 24
24	24	0	5.00		1 00	1.00
0	0	500	—		2.00	2.70
24	0	500	—		4 88	4.24
0	24	500	—		1.00	1.00
24	24	500	—		1.00	1.00
Least difference significant at			0 05	0.89	1 14	0.83
			0.01	1.24	1.58	1.18
			0.001	1.71	2.18	1.67

*On scale ranging from 1.00 for all fruit still on tree to 5.00 for 75 to 100 per cent of fruit dropped to ground. Rating given are averages for plots with and without dolomite, which material did not affect fruit maturity

**On scale ranging from 1 00 for healthy foliage to 5.00 for all leaves showing scorch.

†On scale ranging from 1 00 for all foliage on tree, to 5.00 for tree completely defoliated.

Scorch and Defoliation:—The trees were rated for defoliation and scorch at the same time and in the same manner as described for fruit maturity. The data show a very strong relationship between the incidence of scorch and leaf fall, indicating perhaps that the scorch was responsible for most of the premature defoliation. Although there was a tendency for both dolomite and nitrogen to increase the incidence of scorch and premature defoliation, the effects were statistically significant only when both were applied together in the absence of potash, in which case practically 100 per cent of the leaves were scorched and the trees were practically defoliated at the time of rating. However, when applied with potassium neither nitrogen nor dolomite nor the combination of the two had any harmful effect. Since neither nitrogen nor dolomite had any significant effect on growth of cover crop and since the scorch and premature defoliation are known to be associated with the deficiency of potassium, it may be inferred that the dolomite and nitrogen reduced uptake of potassium by the tung trees.

Summary

Potassium, 24 pounds K_2O per acre, applied to the cover crop at planting time in the fall, increased the yield of lupine by 87 per cent and there was a corresponding average increase of 13.6 pounds of air-dry tung fruit per tree and an average increase of 2.2 in percentage of oil in the fruit. The potassium also hastened maturity of fruit and eliminated scorch and premature defoliation of the type characteristic of potassium deficiency. Dolomite had no significant effect upon the yield of cover crop, yet it decreased the average yield of tung by 8.4 pounds of air-dry fruit per tree and reduced the average oil content of the fruit by 0.8 in percentage value. It is presumed that the effect of dolomite was a direct effect upon the uptake of potassium by the tung trees. It is noted that, in general, the effect of dolomite was most pronounced when it was applied together with nitrogen, which was in the form of ammonium nitrate.

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Breakage of Apple Trees[1]

By ISADOR AARON and WILLIAM S. CLARKE, JR., *Pennsylvania State College, State College, Penn.*

THE study reported here deals with the causes of the breakage of apple limbs carrying a heavy crop during the season of 1935. Some varieties of apple trees suffered severe breakage, while others carrying equally heavy crops suffered very little damage. To investigate the causes of damage, studies were made of the anatomy of the limb tissues of several varieties of apples, cross-sections of limbs being made and studied under the microscope.

MATERIALS

The orchard in which these trees were located was one of those of the Pennsylvania State College at State College in the central part of the State. The trees were planted in the spring of 1908 and were therefore 28 years of age at the time this study was made. In this orchard was a large block of three varieties consisting of York Imperial, Stayman Winesap, and Baldwin. All three varieties bore large crops, but breakage of limbs was severe in the Stayman Winesap, somewhat less in the Baldwin, and seldom occurred in the York Imperial. The object of the study was to determine whether there were anatomical differences in the structure of the wood tissues of these three varieties which would account for the differences in the amounts of breakage among them.

Ten to 15 limbs of each of the three varieties were removed for study during the first 3 months of 1936. The studies were made from broken and intact limbs of injured trees and also from limbs of trees in which no injury occurred. Transverse sections of these limbs were cut and prepared by the usual botanical techniques.

OBSERVATIONS

Gross Breakage:—The breaks in the limbs might appear anywhere along the limbs and were not confined to the crotches. The limbs were not all large, some of the affected ones being as small as 2 inches in diameter. No decay was present in them.

The types of breakage differed among the three varieties. The limbs of Stayman Winesap tore rather than broke, exposing long, ragged, diagonal surfaces. Breaks in the Baldwin were relatively transverse and less ragged. When York Imperial showed injury, the breaks were slightly oblique and the surfaces relatively even.

Anatomical Studies:—The bulk of the xylem tissue in all three

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The authors state here their appreciation for the criticisms of this manuscript by the members of the Departments of Horticulture and Botany of the Pennsylvania State College. They also wish to thank Dr. R. H. Sudds, now of the Horticulture Department, University of West Virginia, for his encouragement in the performance of this study.

varieties of apples was composed of wood fibers, and both the vessels and the wood parenchyma were diffused among the wood fibers. Wood parenchyma occurred in longitudinal rows, each row being in contact with a vessel and with a ray of ray parenchyma. Ray parenchyma extended transversely through both the xylem and the phloem, was one to four cells in width, and was only a few cells deep in a longitudinal direction. Towards the ends of each growing season only wood fibers tended to be produced, so that the periphery of each annual ring was usually composed of this type of cell. At any given point a ray might or might not be in contact with wood fibers alone.

In many of the cross-sections of limbs a type of tissue occurred which might be classed as abnormal. This is defined here as xylem in a parenchymatous condition, and where present, it might compose all or a variable portion of an annual ring, an annual ring being considered as an annual increment. In each of the three varieties a number of annual rings in uninjured and in broken limbs and trees contained some abnormal xylem tissue. The annual rings that contained this abnormal tissue were separated from each other ordinarily by two to four annual rings consisting of normal xylem. The parenchymatous xylem varied both in amount and proportion within an annual ring and in the number of rings showing this condition.

The parenchymatous tissue considered here as abnormal xylem consisted of undifferentiated to partially differentiated cell elements. A differentiated cell is one readily recognized as a parenchyma cell, tracheid, vessel portion, wood fiber, or some other type of normally developed cell. An undifferentiated cell is one normally developed from meristem and still retaining the appearance of parenchyma. The abnormal parenchymatous tissue observed here consisted of cells arrested in development at any stage from origin to maturity, and they were either normal or distorted in shape and anywhere from dwarf to gigantic in size. These cells apparently were destined to be individual fibers, tracheids, vessel portions, and wood parenchyma; but their development was arrested, and they remained in an undeveloped condition. They contained disintegrated protoplasm, which was deposited in cell cavities and permeated the cell walls, especially in those cells that probably would have become vessel portions. The vessel portions retained the slightly oblique cross walls found in both normal and abnormal xylem. Some of the cell elements in the abnormal xylem contained lignin to a small extent, but no pits were observed in any of the cell walls. The cells that would have become fibers were shorter and broader than the wood fibers of normal xylem. Most of the cells of the abnormal xylem were as large or larger than those of normal spring wood, being of tremendous size for tissue formed late in the summer, as they apparently were.

Most of this parenchymatous tissue developed apparently late in the summer. In Stayman Winesap it was produced instead of the small and thick-walled cells of summer xylem, while in York Imperial and in Baldwin it appeared after the formation of normal xylem had ceased. It is thought that this parenchymatous xylem was formed during cool, wet periods late in the summer, and it might be a form of second

growth. In all three varieties a few annual rings contained some abnormal xylem that was apparently formed in midsummer, and a few others had a small amount that was made in the spring. The parenchymatous spring wood was not always present as a separate tissue.

The last portion of xylem formed normally in any year's growth consisted entirely of wood fibers, a thicker band of them being present in the case of Stayman Winesap than in the other two varieties. Many fibers were present also in the xylem formed earlier in the season. Normal wood fibers were long and narrow, in marked contrast to the shorter and broader undeveloped fibers of the abnormal wood. York Imperial very seldom had any abnormal xylem. Baldwin had such xylem more often and in larger amounts. Stayman Winesap contained abnormal xylem more frequently than the other varieties and in the greatest amounts.

York Imperial, as a variety that was relatively free from damage, presented an interesting situation. Where parenchymatous xylem was present, patches of normally developed xylem were often seen to alternate in an irregular manner with the parenchymatous tissue along different radii within an annual ring to make blocks of tissue with this manner of arrangement. Some of the patches of parenchymatous xylem expanded toward the outer edge of the annual ring, so that the periphery of the ring was composed entirely of parenchymatous tissue. Within patches of parenchymatous xylem there were present, and completely enclosed, a few normal vessel segments, fibers, and ray parenchyma cells grouped together as normal xylem.

The differences among trees of a variety as reflected in breakage were directly related to the extent of formation of abnormal xylem. Within a variety all normal xylem in injured and uninjured trees had the same structure. Breakage was associated with a large proportion of parenchymatous tissue and a lack of the usual amount of normal wood fibers.

Discussion

The differences in anatomy between limbs that showed breakage and those that were free from damage were a matter of degree rather than kind. This fact was true for each variety. The results as seen in breakage were the effects of variable anatomical composition and variable load (including the weight of the fruit). A limb that did not break might have broken under a load that was slightly greater. A limb that broke might have remained intact if the load had been less by only a small amount. As the proportion of abnormal xylem increased, the load that a limb could bear decreased. Limbs that bore heavy loads and still remained intact had very small proportions of abnormal xylem, and they might be said to be at the strong end of the range of strong to weak wood.

Breakage, as a consequence of abnormal xylem production, occurred because a sufficient amount of normally differentiated wood fibers had not been formed. The shorter, broader, relatively thin-walled, and unlignified parenchymatous cells that were present instead of true wood fibers were weak structurally as individual cell elements. Cemented

together with only a small amount of overlapping on account of their shortness and greater breadth, the strands and terminal bands of these partially differentiated wood fibers lacked physical strength. A limb might have a number of layers of parenchymatous tissue and would thereby be weakened proportionally.

York Imperial had the least amount of parenchymatous xylem, and this variety was the strongest structurally and showed the smallest amount of breakage. Baldwin contained a larger amount of the abnormal xylem, and breakage was more extensive. Stayman Winesap contained the largest amount of abnormal xylem, and this variety showed the greatest amount of breakage. The susceptibility of the Stayman Winesap to breakage seemed to be associated with the formation of relatively large amounts of weak parenchymatous xylem.

Summary

The relationship between the breakage of limbs among three varieties of apples and their anatomical structure was investigated by means of studies of the cross-sections of the wood of broken and unbroken limbs. All three varieties bore large crops of fruit but varied in the incidence of broken limbs caused by the crop. In the wood of each of these varieties some abnormal xylem was found. This abnormal xylem consisted of masses of cells in a parenchymatous condition where wood fibers, or in some cases vessels and tracheids, would have been ordinarily. York Imperial contained little of this abnormal xylem and exhibited only a small amount of breakage. Stayman Winesap contained the greatest amount of this abnormal xylem and exhibited the largest amount of breakage. Baldwin was intermediate both in amount of abnormal xylem and in amount of breakage.

Some Effects of Limb and Fruit Injections with Ascorbic Acid and Calcium Salts on Apple Fruits[1]

By R. M. Smock and C. R. Gross, *Cornell University, Ithaca, N. Y.*

It is known that softening changes in apples following harvest are associated with a breakdown of protopectin into soluble pectin compounds. It was formerly assumed that this hydrolysis was accomplished by pectic enzymes in the fruit. Work by Griffin and Kertesz (1) showed that the enzymes protopectinase and pectin galacturonase were not present in apple tissue. They demonstrated with *in vitro* experiments on the apple that this hydrolysis could be accomplished by tissue treatment with ascorbic acid or hydrogen peroxide or both. It is known that apples do contain ascorbic acid in amounts varying rather widely among varieties. It has been shown that ascorbic acid exists in apples as l–ascorbic and as dehydroascorbic acid, with the latter decreasing in proportion as the fruits mature on the tree (5). The work of Hackney (2) suggested that ascorbic acid might play a role as a respiratory catalyst in apple tissue. She found that when cells from apple flesh were dipped in ascorbic acid the respiration rate was increased. This effect was not found on cells from the skin of the fruit where most of the ascorbic acid is located.

Not only is there this effect of ascorbic acid on the softening rate of apple tissue (1) but it is well known that treatment of apple slices with calcium chloride or calcium lactate results in a "firming" action (3). Following such treatments the slices do not disintegrate or fall apart so readily on cooking.

In view of this background the authors wondered if it would be possible to influence the softening rate, respiration, and soluble pectin of apples as a result of limb and fruit injections with ascorbic acid and calcium salts.

Methods

Limb injections were made with 4 liters of aqueous solutions containing from .8 to 2.0 per cent of ascorbic acid or .5 per cent calcium chloride ($CaCl_2 \cdot 2\ H_2O$). The limbs used as controls were either untreated or injected with 4 liters of water. Tables I and II indicate the type of controls used. The injections were made by gravity into limbs about 4 inches in diameter, taking care to exclude air from the injection holes. Comparisons were always made between treated and control limbs on the same tree.

Limbs were sprayed with a 1 per cent solution of ascorbic acid by means of a hand sprayer.

Fruit injections were made through secondary growth from spurs according to the method of Levy (4). Ascorbic acid was used in .3 and .5 per cent solutions. Calcium lactate ($Ca(C_3H_5O_3)_2 \cdot 5\ H_2O$) in .3 and 5 per cent solutions was used. Thirteen cubic centimeters of liquid were injected into each shoot. Twenty-five fruits were injected in each treatment on each tree.

[1]The authors wish to express their appreciation to Dr. Z. I. Kertesz who suggested the injection of calcium salts and who conducted the pectin analyses.

Within 24 hours after harvest the ascorbic acid content of the fruits was determined by the dichlorophenol indophenol titration method. Pectin analyses were made by the method described by Griffin and Kertesz (1) in Dr. Kertesz's laboratory. Firmness of the fruit was determined on 10 to 20 fruits from each treatment with a Magness-Taylor pressure tester. Respiration measurements were made at 74 degrees F by the conventional procedure of absorption of evolved carbon dioxide in sodium hydroxide solution and titrating the excess sodium hydroxide after adding barium chloride.

Results

Toxicity

Some marginal leaf burning followed injection of limbs with 1.5 and 2.0 per cent ascorbic acid solutions. No injury was observed with 1.0 per cent solutions. Only the 1.0 per cent injection results are included for this reason. Incipient or severe burning of the leaves followed calcium chloride injection of the limbs. Hence, all results from limb injections with calcium chloride are open to considerable question. They are reported here just for the record.

No burning of the leaves was noted in any of the fruit injections with .3 and .5 per cent ascorbic acid and .3 and .5 per cent calcium lactate. It is possible that even stronger solutions could have been used in these fruit injections.

No leaf injury was noted with 1 per cent ascorbic acid sprays.

Ascorbic Acid Content of the Fruit

The results on ascorbic acid analyses appear in Table I. Limb sprays with ascorbic acid did not increase the ascorbic acid content of the fruit in four experiments. Limb injections with 1 per cent ascorbic acid increased the ascorbic acid content of the fruit rather markedly in two cases in eight experiments. In three cases it increased the content slightly but not significantly. In one case there was no effect and in two cases there was a decrease.

Injections of fruits with ascorbic acid did not give consistent increases or decreases in the amount of this material in the fruit.

The variability in results with limb and fruit injections with ascorbic acid would indicate no consistent effect on the amount of ascorbic acid in the fruits at harvest time.

Injections of limbs and fruits with calcium salts did not have any clear cut effects on ascorbic acid in the fruits at harvest.

Fruit Firmness at Harvest

The data on fruit firmness are given in Table II. With but two exceptions, it will be noted that water injection into the limbs had no particular effect on fruit firmness.

Limbs injections with ascorbic acid gave increases in fruit firmness at harvest time in eight out of 13 cases. In four more cases there was a slight increase. In one case there was a slight but insignificant decrease. It should be noted that this slight decrease and one of the cases of a

TABLE I—ASCORBIC ACID CONTENT OF TREATED AND UNTREATED FRUITS AT HARVEST

Variety	Harvest Date	Days Since Treated	Ascorbic Acid in Mg/100 G Fruit Tissue				
			Untreated	HOH	Ascorbic Acid	Calcium Chloride	Calcium Lactate
			*Limb Injections**				
Duchess	Aug 16, 1948	35	10.0	7.4	8.2	6.1	—
Wealthy	Sep 1, 1947	45	4.6	—	5.0	5.5	—
Wealthy	Sep 7, 1948	20	4.0	2.9	3.5	4.0	—
R. I. Greening	Sep 9, 1947	29	2 8	—	5.3	6.0	—
McIntosh	Sep 18, 1947	23	—	3.4	2.7	2.8	—
McIntosh	Sep 18, 1947	38	3 4	3 3	4 1	3.4	—
McIntosh	Sep 18, 1947	62	-	3.7	3 7	3 3	—
Northern Spy	Oct 22, 1948	29	5.4	4.5	10.0	6.3	—
			*Limb Sprays***				
Duchess	Aug 16, 1948	35	10.0	-	7.4	—	—
Wealthy	Sep 1, 1947	45	4.6		4 8	—	—
R. I Greening	Sep 9, 1947	29	2 8	- -	3.0	—	—
McIntosh	Sep 18, 1947	38	3 4	- -	2.8	—	—
			Fruit Injection†				
Duchess	Aug 11, 1949	17	-	12 7	7 0	...	8 9
Duchess	Aug 11, 1949	49	-	12 8	9 6		9 4
Duchess	Aug 11, 1949	51		8 1	9 0		—
Duchess	Aug 11, 1949	57	-	9 9	—	-	8 0
Duchess	Aug 11, 1949	58		7 0	9 0	- -	—

*Limb injections with 4 liters of each of the following water, 1 per cent ascorbic acid, and 0.5 per cent calcium chloride

**Limb sprays with 1 per cent ascorbic acid

†Fruit injections with 13 cc of each of the following, water, 0.3 and 0 5 per cent ascorbic acid and 0 3 and 0 5 per cent calcium lactate.

slight increase came with injections made only a week or two before harvest. It could be said that with treatments made over 2 weeks before harvest limb injections with ascorbic acid resulted in increased firmness of the fruit at harvest time.

Fruit injections with ascorbic acid made over 2 weeks before harvest resulted in increased firmness. Injections made just 2 weeks before harvest resulted in slight decreases in firmness.

Limb sprays with ascorbic acid resulted in firmer fruit at harvest time in four out of seven cases. In two cases there was no effect but in one there was a slight decrease. More work would have to be done with these limb sprays to draw any conclusions.

Results with limb injections with calcium chloride gave erratic results on fruit firmness. These results were undoubtedly complicated by the leaf injury factor. It was observed that the more intense the leaf injury the more likely the treated fruits were to be softer than the controls.

Fruit injections with calcium lactate resulted in firmer fruit when the injections were made more than 2 weeks before harvest. The number of tests was rather limited, however.

In one experiment a solution containing both ascorbic acid and calcium lactate (.5 per cent each) was injected into McIntosh fruits 47 days before harvest. This treatment resulted in firmer fruits (see Table II).

TABLE II—FIRMNESS OF TREATED AND UNTREATED FRUITS AT HARVEST

Variety	Harvest Date	Days Since Treated	Firmness of Fruits (Pounds)					
			Un-treated	HOH	As-corbic Acid	Calcium Chlor-ide	Calcium Lactate	Ascorbic + Calcium Lactate
			*Limb Injections**					
Duchess	Aug 16, 1948	35	15.0	15.0	16.9	15.3	—	—
Wealthy	Sep 14, 1947	45	15.6	—	16.0	15.6	—	—
Wealthy	Sep 7, 1948	20	13.0	12.7	15.1	13.6	—	—
R. I. Greening	Sep 9, 1947	29	23.4	—	25.6	24.3	—	—
R. I. Greening	Sep 9, 1947	14	23.4	—	23.7	22.7	—	—
McIntosh	Sep 18, 1947	7	15.3	15.3	15.0	16.4	—	—
McIntosh	Sep 18, 1947	23	15.6	15.6	16.6	15 0	—	—
McIntosh	Sep 18, 1947	38	15 0	15.2	16.4	15.3	—	—
McIntosh	Sep 18, 1947	62	15.3	14.7	16.0	15.6	—	—
McIntosh	Sep 24, 1948	20	13.7	12.0	14 1	12.0	—	—
McIntosh	Sep 24, 1948	20	13.2	13.4	13.6	12.3	—	—
Northern Spy	Oct 22, 1947	29	15.8	15.7	18.1	17.0	—	—
Northern Spy	Oct 12, 1948	26	19.5	19.6	20.2	—	—	—
			*Limb Sprays***					
Duchess	Aug 16, 1948	35	15.0	—	15.1	—	—	—
Wealthy	Sep 1, 1947	45	15.6	—	15 1	—	—	—
R. I. Greening	Sep 9, 1947	29	23.4	—	24.9	—	—	—
R. I. Greening	Sep 9, 1947	14	23.4	—	24 5	—	—	—
McIntosh	Sep 18, 1947	7	15.3	—	16 1	—	—	—
McIntosh	Sep 18, 1947	38	15 0	—	16 3	—	—	—
McIntosh	Sep 18, 1947	62	15.3	—	15.3	—	—	—
			Fruit Injections†					
Duchess	Aug 11, 1949	15	—	16.1	15 7	—	—	—
Duchess	Aug 11, 1949	17	—	17.2	16 7	—	17.4	—
Duchess	Aug 11, 1949	49	—	15.5	16.6	—	17.9	—
Duchess	Aug 11, 1949	51	—	16.4	17.8	—	—	—
Duchess	Aug 11, 1949	57	—	15.7	—	—	18.9	—
Duchess	Aug 11, 1949	58	—	16.0	17.4	—	—	—
McIntosh	Sep 13, 1949	47	—	15.7	—	—	—	17 7

*Limb injections with 4 liters of each of the following: water, 1 per cent ascorbic acid, and 0.5 per cent calcium chloride.
**Limb sprays with 1 per cent ascorbic acid.
†Fruit injections with 13 cc of each of the following: water, 0.3 per cent and 0.5 per cent ascorbic acid and 0.3 per cent and 0.5 per cent calcium lactate.

SOLUBLE PECTIN

Soluble pectin determinations were made in only one experiment. The results appear in Table III.

The limited data in Table III suggest that both the ascorbic acid and the calcium chloride injections resulted in a retarded breakdown of the protopectin to soluble pectin. This observation can only be suggestive since protopectin determinations were not made. The work of Griffin and Kertesz (1) would have suggested an accelerated hydrolysis but their work involved dipping apple tissue in ascorbic acid solutions. Both their investigation and this one suggest a possible role of ascorbic acid in apples in the softening process. It will be noted in Table III

TABLE III—SOLUBLE PECTIN IN NORTHERN SPY APPLES AT HARVEST TIME AS AFFECTED BY LIMB INJECTIONS

Treatment	Harvest Date	Days Since Treated	Soluble Pectin Mg/100 G (As Ca Pectate)	Firmness (Lbs)
HOH	Oct 22, 1947	29	55.0	15.7
1 per cent ascorbic acid	Oct 22, 1947	29	50.5	18.1
0.5 per cent calcium chloride	Oct 22, 1947	29	49.5	17 0

that the lower soluble pectin contents in the treated fruits was associated with greater fruit firmness at harvest time than in the control.

RESPIRATION

Duchess:—Fig. 1 indicates the effect of limb injections of 1 per cent ascorbic acid and .5 per cent calcium chloride on the respiration of

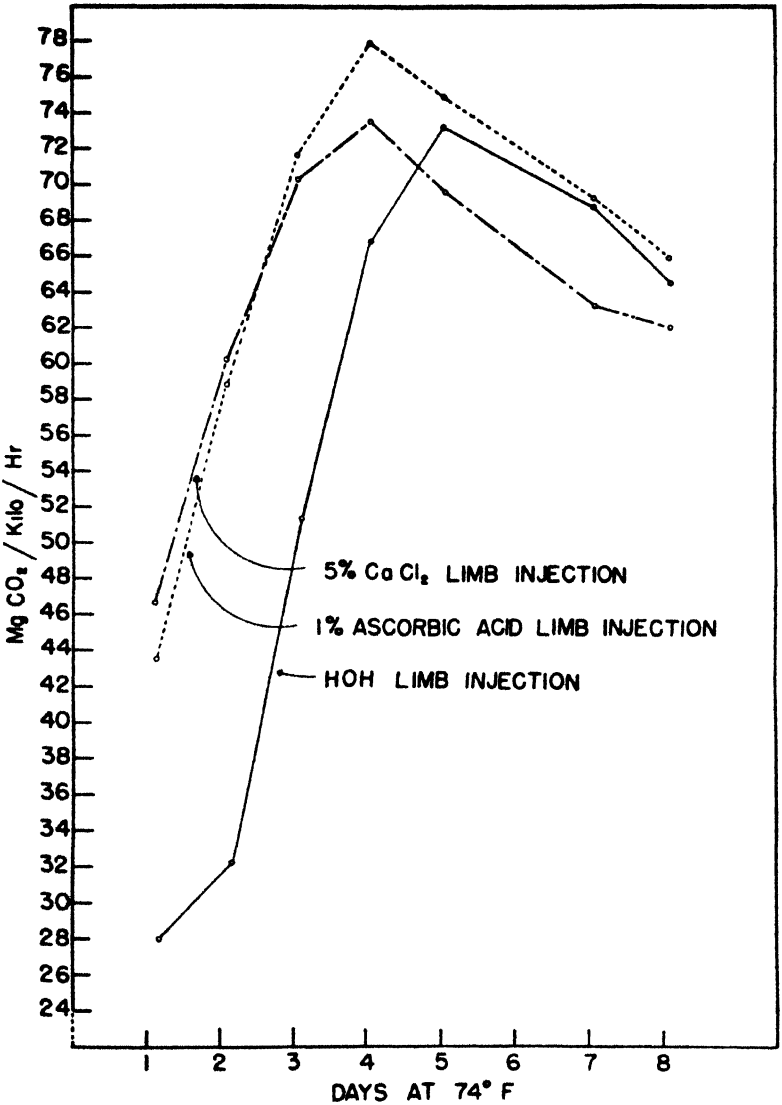

FIG. 1. Respiration of Duchess apples as affected by limb injections. Fruits picked August 16, 1948 which was 35 days after treatments.

Duchess apples after harvest in 1948. Treatments had been made 35 days before harvest. The treated fruits respired more rapidly than the control during the first 4 days and reached the climacteric about 1 day sooner. After the climacteric was passed the rates of all three lots were about the same. Though the results are not given in Fig. 1, a 1 per cent ascorbic acid spray 35 days before harvest resulted in a slightly more rapid respiration rate until the climacteric was reached.

Fig. 2 shows the effect of fruit injections of .3 per cent ascorbic acid and .3 per cent calcium lactate on the respiration of Duchess apples in 1949. The treatments were made 57 days before harvest. During the first 4 days after harvest the respiration rate of the ascorbic acid and calcium lactate treated fruits was slightly slower than the control. The ascorbic acid lot had a slightly higher climacteric than the control and the rate was somewhat more rapid after the climacteric than that of the control.

Wealthy:—The effect of limb injections and a limb spray treatment of Wealthy apples in 1947 is shown in Fig. 3. The treatments were made 45 days before harvest. After the second day, the ascorbic acid injection fruits had a more rapid respiration rate than the controls. Differences between the control and the other treatments did not show up until the seventh day after harvest when there was a slower rate with the calcium chloride and ascorbic acid spray treatments.

The influence of limb injections made 20 days before harvest on Wealthy in 1948 is shown in Fig. 4. The calcium chloride treatment resulted in a slightly faster than normal respiration rate and the ascorbic acid a slightly slower than normal rate. The effect of the calcium chloride should be discounted because of leaf injury.

McIntosh:—The effect of limb injection with ascorbic acid 38 days before harvest on respiration of McIntosh in 1947 is seen in Fig. 5. After the second day and until the seventh day there was a slightly slower respiration rate in the ascorbic acid treated fruit.

Fig. 6 shows the influence of limb injections 23 days before harvest on the respiration of McIntosh in 1947. The ascorbic acid treated fruit had a delayed climacteric rise. The calcium chloride treated fruit had a slightly accelerated climacteric rise in rate. The latter should be discounted because of the injury factor, however.

Rhode Island Greening:—The results of limb injections 14 days before harvest on Greenings in 1947 are not given. These fruits did not start their climacteric rise during the entire 9-day holding period at 74 degrees. There were no significant differences during this period although the ascorbic acid and calcium chloride limb injections resulted in slightly slower respiration rates than the control. In this case the control was untreated (that is, no water injection).

Discussion

It was found that 1 per cent solutions of ascorbic acid could be injected into or sprayed on apple limbs without injury. Stronger solutions caused injury in limb injections. Calcium chloride in the concentration of .5 per cent caused variable amounts of injury when injected

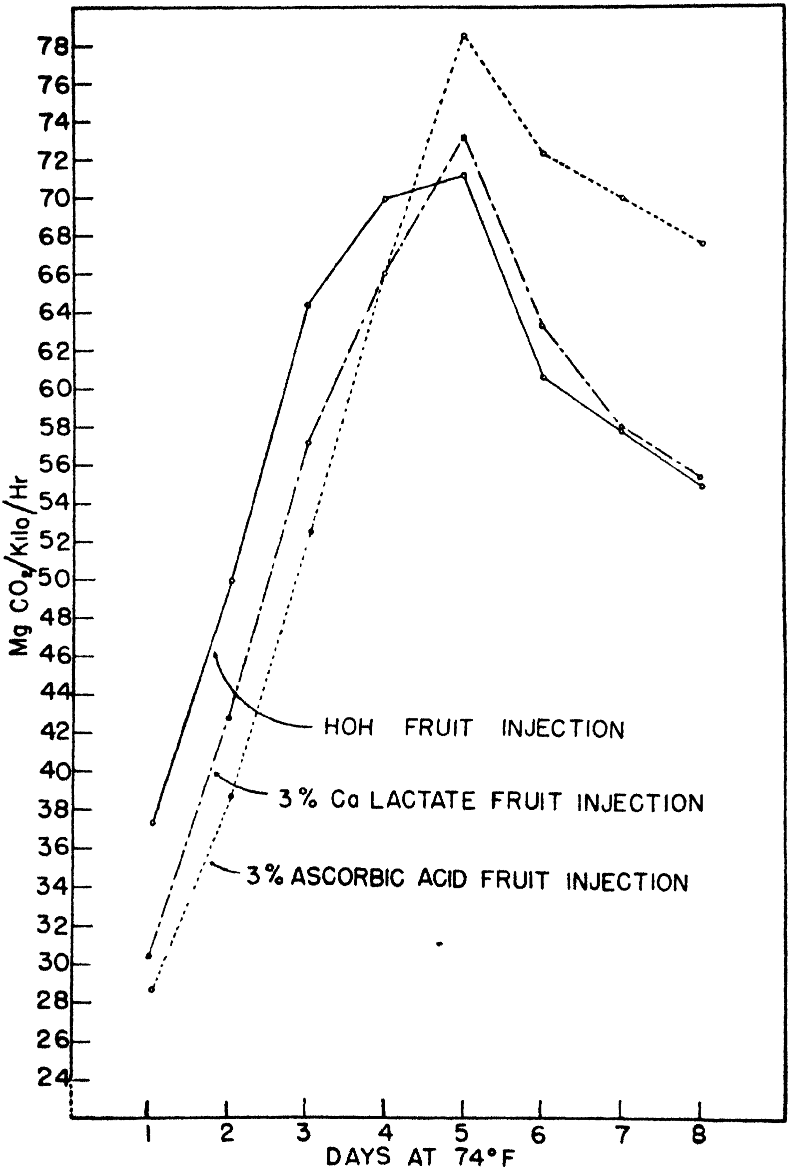

FIG. 2. Respiration of Duchess apples as affected by fruit injections. Fruits picked August 11, 1949 which was 56 days after treatments.

into apple limbs. Ascorbic acid and calcium lactate solutions could be injected in concentrations up to .5 per cent into apple fruits without injury. Stronger solutions were not tried.

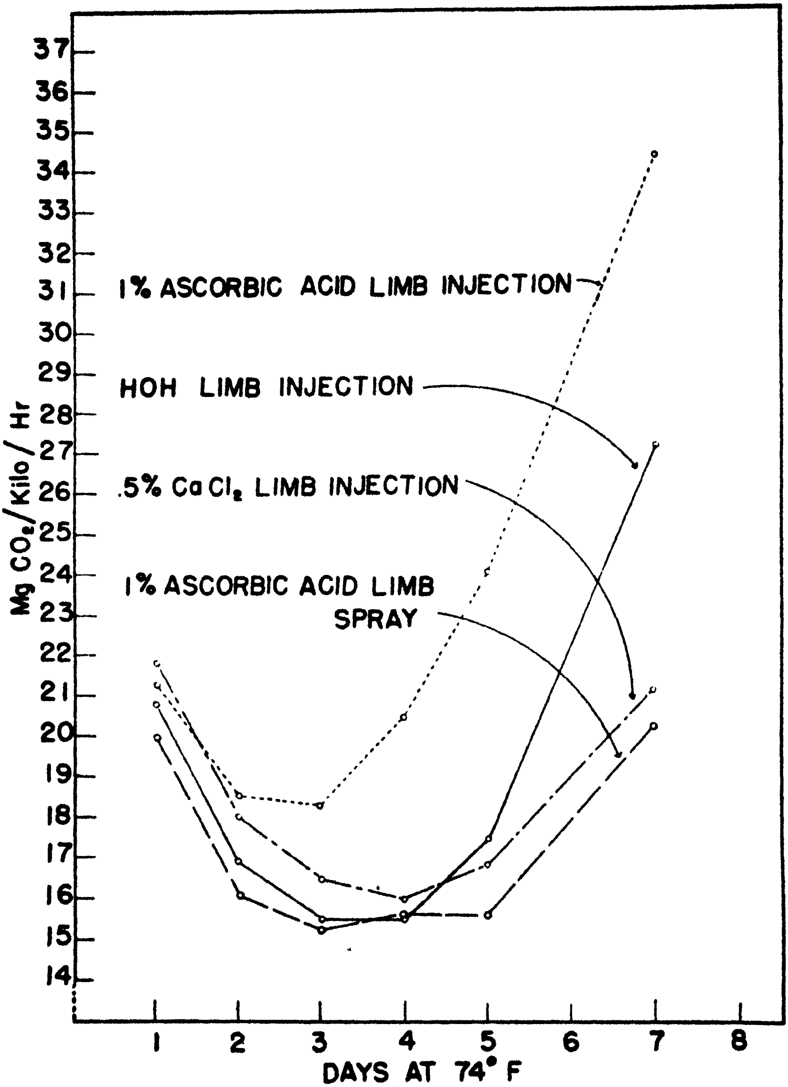

FIG. 3. Respiration of Wealthy apples as affected by limb treatments. Fruits picked September 1, 1947 which was 45 days after treatments.

Limb and fruit injections and limb sprays with ascorbic acid gave erratic results on ascorbic acid content of the fruit at harvest time. In only two cases was there a marked increase in ascorbic acid content as a result of injections. Theoretically, sufficient ascorbic acid was injected to markedly increase the ascorbic acid content of the fruit. Why more significant increases were not found is not known. It is possible

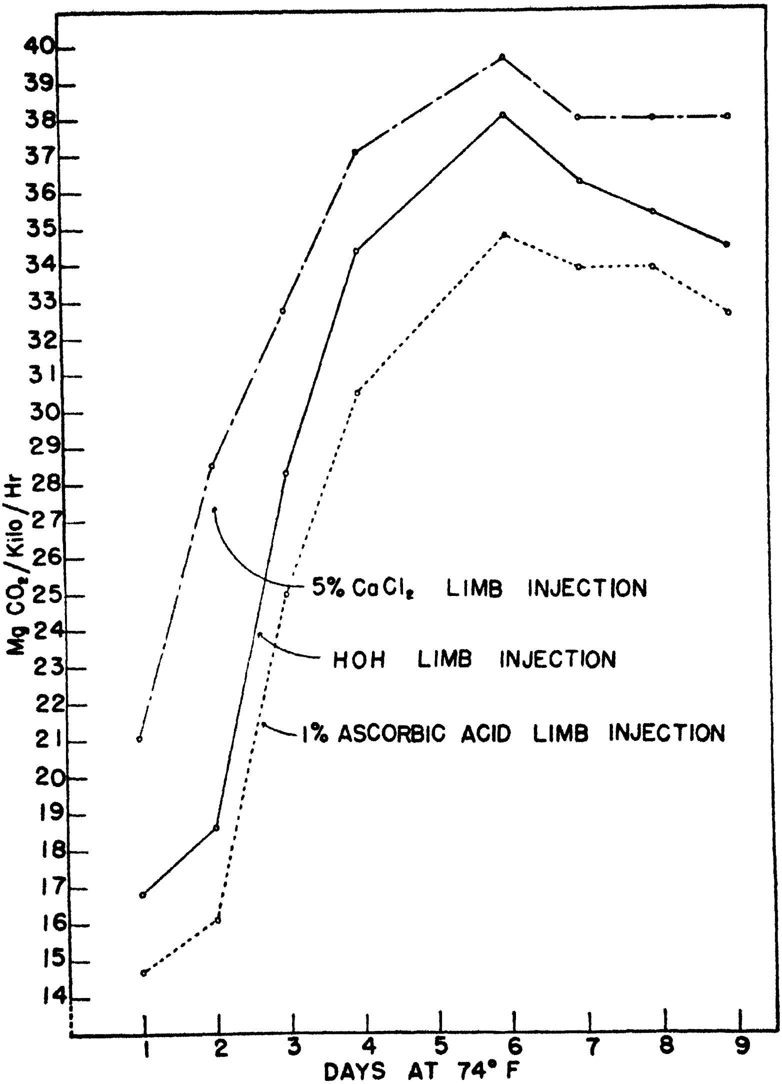

FIG. 4. Respiration of Wealthy apples as affected by limb injections. Fruits picked September 7, 1948 which was 20 days after treatments.

that the injected material never got to the fruit but nevertheless influenced fruit firmness and respiration. It is also possible that the injected ascorbic acid degraded before analyses were made. Limb and fruit injections with calcium salts showed no consistent increase or decrease in ascorbic acid content of the fruit.

When limbs and fruits were injected with ascorbic acid more than 2

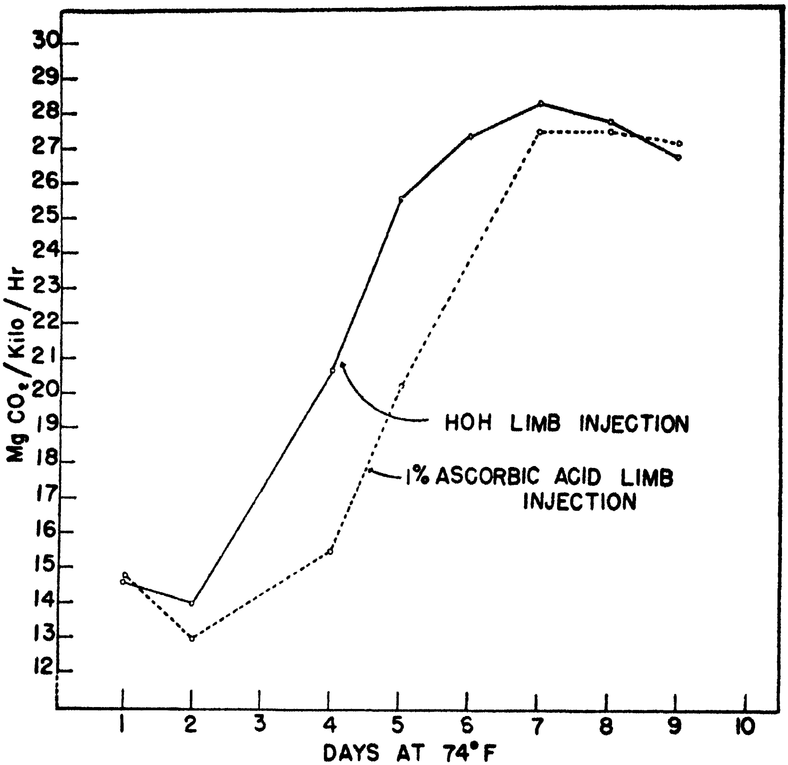

FIG. 5. Respiration of McIntosh apples as affected by limb injections. Fruits picked September 18, 1947 which was 38 days after treatment.

weeks before harvest there was increased fruit firmness at harvest time. The work of Griffin and Kertesz (1) suggested that the reverse might be found but their work was done with fruit tissue with *in vitro* experiments after the fruits were harvested. Both their work and this investigation suggest that ascorbic acid does play a role in fruit softening, however. More work needs to be done to establish what this role is and what the magnitude of the role is. Spraying limbs with 1 per cent ascorbic acid gave erratic results with regard to fruit firmness. In some cases the fruits were firmer following treatment but conclusive evidence was not obtained.

When limbs were injected with calcium chloride the results on fruit firmness were erratic, probably due to the injury factor. A limited number of fruit injections with calcium lactate indicated that when treatment was made more than 2 weeks before harvest the injected fruits were firmer than the controls at harvest time.

The very limited data on soluble pectin obtained indicated that ascorbic acid and calcium salt injections resulted in lower values at harvest time in Northern Spy. If these data can be corroborated it

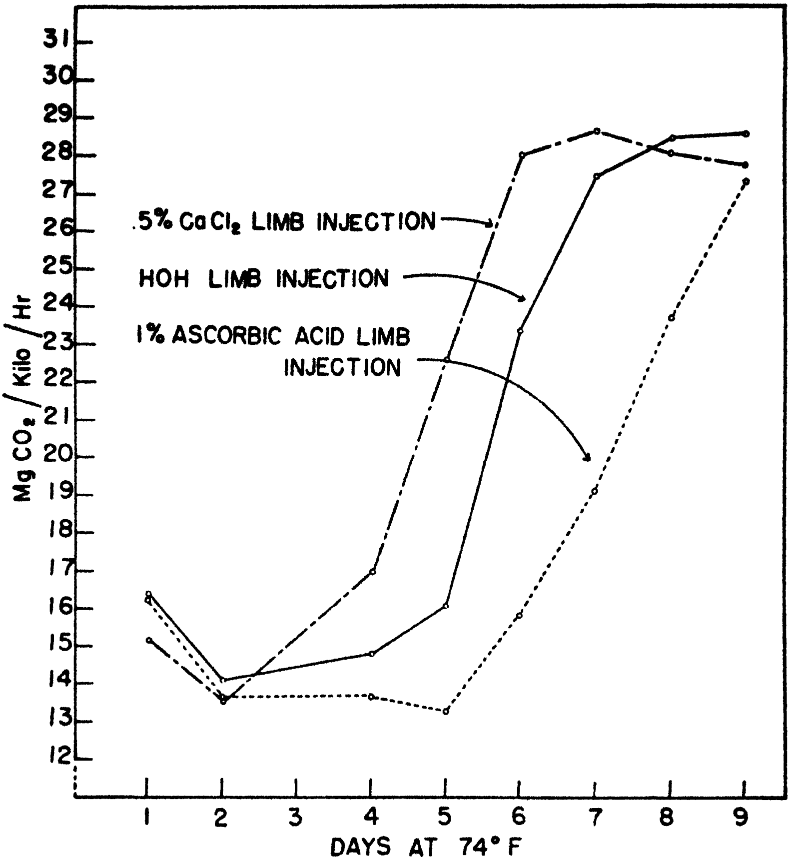

FIG. 6. Respiration of McIntosh apples as affected by limb injections Fruits picked September 18, 1948 which was 23 days after treatment.

would indicate that these materials result in a retarded hydrolysis of protopectin in the fruit prior to harvest.

No clear cut conclusions can be drawn from the respiration data. In seven tests with ascorbic acid injections a decreased respiration rate in the pre-climacteric phase occurred in five cases. In one of these cases the decrease was not significant, however. In two cases there was a significant increase in the pre-climacteric phase with the ascorbic acid injected fruit. Why there should have been increased rates in some cases and decreased rates in others is not known. The work of Hackney (2) with apple tissue with *in vitro* experiments after harvest would have suggested that increases should have been expected had sufficient ascorbic acid been injected. The respiration experiments in this study should have been continued farther into the post-climacteric phase. In one instance, for example, there was a decrease in rate in the pre-climacteric phase and an increase in the post-climacteric phase as com-

pared to the control. Variety, season, and the interval of time between date of treatment and harvest may all have a bearing on the effect of ascorbic acid treatment on respiration rate. This study does suggest however, that ascorbic acid treatments may have an effect on respiration.

Respiration results with calcium chloride treatments should be discounted because of the injury factor. In one test with calcium lactate there was a decreased rate of respiration in the preclimacteric phase only.

Further study of this subject might well be concentrated on fruit injections of ascorbic acid and calcium lactate and possibly concentrations higher than .5 per cent of the latter could be used. Sprays covering the underside of the leaves should be tried. The effects of date of injection should be explored more fully. Data on fruit firmness, ascorbic acid content of the fruit, soluble pectin analyses, and respiration rates through senescence should be collected.

Summary

Limb and fruit injections with ascorbic acid resulted in firmer apples at harvest time if the injections were made more than 2 weeks before harvest.

Limited data suggested that fruit injections with calcium lactate resulted in firmer fruit if the injections were made 2 weeks before harvest. Fruit firmness data following calcium chloride injections of limbs were undependable because of the injury factor.

Limited data indicated that injection of limbs with ascorbic acid and calcium chloride gave lower soluble pectin values in the fruit at harvest time.

Ascorbic acid injections in limbs and fruits usually depressed the respiration rate of apples in the pre-climacteric phase but sometimes accelerated the rate. The data do suggest that such injections may influence respiration rate.

Ascorbic acid analyses of the fruits at harvest following injections of ascorbic acid and calcium salts do not indicate any consistent effect although in a few cases there was a significant increase.

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Chemical Changes During Storage of Dehydrated Stayman Winesap Apples as Influenced by Storage Temperature and Pack Atmosphere[1]

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DURING the war years, investigations were carried out at the Maryland Agricultural Experiment Station on pilot tunnel dehydration of some of the important fruits and vegetables of the region. A previous report by the authors (7) described some of the general results of the apple dehydration and storage work. It is the purpose of this paper to present some of the chemical changes which took place during storage in dehydrated Stayman Winesap apples, particularly as influenced by storage temperature and pack atmosphere.

MATERIALS AND METHODS

For a complete description of the methods of processing, the reader is referred to the previous paper (7), of which only the more pertinent information is repeated here.

Hand-picked, medium-sized Stayman Winesap apples were used. Immediately after harvest in 1943, the fruit was stored at 33 degrees F until December, when an average pressure test of 12 pounds indicated a satisfactory condition for processing. Since sulfur content of dehydrated apples was considered important in the storage life of the product (5), the following treatments were used, together with a standard dehydration for all lots:

- Lot 120 Standard sulfuring for 30 minutes at the rate of 10 pounds of SO_2 per ton of fruit.
- Lot 121 Standard sulfuring (as for lot 120), plus re-sulfuring after dehydration for 24 hours at the rate of 10 pounds per ton of fruit.
- Lot 122 Standard sulfuring (as for lot 120), plus re-sulfuring after dehydration for 24 hours at the rate of 20 pounds per ton of fruit.
- Lot 123 Standard sulfuring (as for lot 120), followed immediately by a 30-second steam blanch plus re-sulfuring after dehydration for 24 hours at the rate of 20 pounds per ton of fruit.
- Lot 124 Standard sulfuring (as for lot 120), followed by a standard dehydration plus 8 additional hours of drying until a moisture content of 2.9 per cent was reached.

After a conditioning period of several days in covered wooden trays (except for lot 124) to insure a uniform moisture content in the dried material, each lot was divided into three portions which were sealed

[1]Scientific Publication No. A238, Contribution No. 2169, of the Maryland Agricultural Experiment Station (Department of Horticulture).

in air, carbon dioxide and vacuum, respectively, in standard No. 2 tin cans. The machine used for sealing the cans provided a nearly perfect vacuum within the can for the vacuum pack. On January 20, 1944, a portion of each sealed lot was placed in 33, 65, and 100 degrees F storage. The latter rather high temperature was included to approach temperatures prevailing in desert or tropical regions, and hence of special interest to the armed forces.

Samples for analyses were taken at 90-day intervals from that fruit stored at 33 and 65 degrees F, and at more frequent intervals from samples stored at 100 degrees, since deterioration at this latter temperature took place more rapidly. Ascorbic acid was determined by the method of Bessey and King (1), after first neutralizing the sulfur according to the report of Mapson (3). Modifications by Mrak (4) of the method of Nichols and Reed (6), were used to determine sulfurous acid in the samples. Sugars and starch were determined by the Heinze and Murneek modification of the Shaffer-Somogyi method (2).

Each sample of fresh fruit for analysis was made up of two pie-shaped segments of flesh only, taken from each of 20 apples. In preparation for dehydration, the fresh apples, after coring and peeling, were divided longitudinally by machine into 16 pie-shaped sections. Each sample of dehydrated fruit for chemical analysis consisted of a minimum of 130 of the dried sections. Duplicate determinations were made for all chemical data reported.

Results

Storage at 33 and 65 Degrees F:—Since this work was primarily concerned with preservation in high temperature storage, the material at 33 and 65 degrees was limited to air packs of the various sulfur treatments. Cumulative losses of sulfurous acid and ascorbic acid from dehydrated apples stored at these two lower temperatures are summarized in Table I. From these data it is evident that in nearly every case the greatest decrease in sulfurous acid occurred in the first 90 days of storage. With the exception of lot 120 at 65 degrees, and lot 121 at 33 degrees, all lots showed a progressive decrease in sulfurous acid during storage, and these losses are shown to be significant. Storage temperatures definitely influenced the amount of sulfurous acid loss for, with one exception, all lots had significantly greater loss at 65 degrees than at 33 degrees F.

The loss of ascorbic acid from the various samples stored at 33 and 65 degrees F was not marked, but the sulfur treatments, as well as the storage intervals, did result in significant differences in ascorbic acid loss as determined by analysis of variance of cumulative losses in Table I. The lots 122 and 123, which received the heaviest sulfuring, showed the best retention of ascorbic acid during storage, and differences in favor of sulfuring treatments were highly significant, as were the differences produced by the length of time the samples were stored. Except for lot 123, the greatest loss of ascorbic acid occurred during the first 90 days of storage. Ascorbic acid in lot 123 remained near the initial

TABLE I—CUMULATIVE LOSSES OF SULFUROUS ACID AND ASCORBIC ACID, SHOWN BY ANALYSIS DURING STORAGE, IN DEHYDRATED STAYMAN WINESAP APPLES AS AFFECTED BY STORAGE TEMPERATURE AND BY TREATMENTS* AT THE TIME OF DEHYDRATION

Days Stored	Cumulative Loss** of Sulfurous Acid (Ppm)		Cumulative Loss† of Ascorbic Acid (Mg/100 Gr)	
	33 Degrees F Storage	65 Degrees F Storage	33 Degrees F Storage	65 Degrees F Storage
		Lot 120		
90	70	142	1.5	1.7
180	128	161	2.2	2.4
270	197	149	2.6	3.0
		Lot 121		
90	60	131	1.4	1.9
180	50	157	2.2	1.8
270	103	227	2.7	2.2
		Lot 122		
90	57	207	0.9	2.0
180	97	217	1 3	1.7
270	111	235	2.0	1.9
		Lot 123		
90	158	271	0 1	0 3
180	168	258	0.1	0.2
270	231	347	1.1	1.2

*Lot 120, sulfured at 10 lbs/ton, dried, lot 121, sulfured at 10 lbs/ton, dried, re-sulfured at 10 lbs/ton; lot 122, sulfured at 10 lbs/ton, dried, re-sulfured at 20 lbs/ton; lot 123, sulfured at 10 lbs/ton, steam-blanched 30 seconds, dried, re-sulfured at 20 lbs/ton.

**Differences necessary for significance: between temperatures—100.6 at 5 per cent point; between storage intervals—28.6 at 1 per cent point.

†Differences necessary for significance: between lot treatments—0.508 at 1 per cent point; between storage intervals—0.252 at 1 per cent point.

level at both temperatures. This is evidence that the steam blanch was of some value in increasing retention of ascorbic acid through the storage period. No significance can be attached to differences between temperature treatments.

Sugar determinations (not presented in tables) on samples stored at 33 and 65 degrees F showed no significant change in any treatments during the storage period. With some variations, reducing sugars remained essentially at a constant level, as did non-reducing and total sugars. These data were not in agreement with results of some earlier storage work of 1943 where a gradual accumulation of reducing sugars was found in dehydrated apples held in cold and common storage for 1 year. This possibly can be explained on a basis of results of qualitative enzyme determinations. In all samples stored during the earlier work of 1943, a positive peroxidase test was obtained; in the fruit stored in this later work, a negative peroxidase reaction with guaiacol resulted. Thus, enzyme activity could have been responsible for reducing sugar accumulation previously recorded.

The flavor, color and general appearance of all samples stored at both 33 degrees and 65 degrees was essentially the same after 9 months of storage compared to the condition at the beginning of the storage period. No difference could be detected in visible characteristics, and no off-flavors or hay-like odors developed under either storage temperature.

Storage at 100 Degrees F:—The progressive stages of darkening of the dehydrated apples stored at 100 degrees F have been pictured and described (7). Table II presents the ascorbic acid content of samples taken at intervals during 270 days of 100 degrees F storage. Losses of ascorbic acid were closely correlated with decreases in sulfurous acid throughout the storage period (Table III). Lot 120, which received

TABLE II—ASCORBIC ACID CONTENT, EXPRESSED AS MILLIGRAMS PER 100 GRAMS, OF DEHYDRATED STAYMAN WINESAP APPLES STORED AT 100 DEGREES F

Lot No.*	Nature of Pack	Initial Sulfurous Acid Content (Ppm)	Moisture After Dehydration (Per Cent)	Days Stored						
				0	36	60	90	120	150	270
120	Air	1,321	13.5	10.2	5.1	4.3	4.1	2.0	0	0
120	Vacuum	1,321	13.5	10.2	7.1	4.8	5.0	4.4	0	0
120	CO_2	1,321	13.5	10.2	5.5	5.0	4.4	3.3	0	0
121	Air	1,351	13.0	10.3	6.5	4.5	4.5	2.4	0	0
121	Vacuum	1,351	13.0	10.3	7.7	6.0	6.4	4.7	0	0
121	CO_2	1,351	13.0	10.3	5.8	5.2	5.5	4.0	0	0
122	Air	1,407	12.8	10.0	6.6	5.0	4.6	2.8	0	0
122	Vacuum	1,407	12.8	10.0	8.3	7.2	6.8	6.0	4.3	0
122	CO_2	1,407	12.8	10.0	6.9	5.3	4.9	4.2	0	0
123	Air	1,768	11.0	9.6	8.1	5.1	4.8	3.2	0	0.
123	Vacuum	1,768	11.0	9.6	9.0	7.8	7.4	6.4	5.2	0
123	CO_2	1,768	11.0	9.6	8.7	7.2	6.0	5.6	4.7	0
124	Air	1,466	2.9	10.1	—	-	8.4	—	5.6	3.4

*See "Materials and Methods" for treatments.

TABLE III—SULFUROUS ACID CONTENT, EXPRESSED AS PARTS PER MILLION OF DEHYDRATED STAYMAN WINESAP APPLES STORED AT 100 DEGREES F. STAGES OF DARKENING* ALSO ARE SHOWN TO CORRELATE WITH SULFUROUS ACID CONTENT

Lot No.*	Nature of Pack	Days Stored						
		0	36	60	90	120	150	270
120	Air	1,321	875 (II)†	405 (IV)	259 (V)	0	0	0
120	Vacuum	1,321	1,099	798 (II)	538 (IV)	226 (V)	186	173
120	CO_2	1,321	988 (II)	585 (IV)	353 (V)	82	0	0
121	Air	1,351	964	746 (II)	571 (IV)	123 (V)	0	0
121	Vacuum	1,351	1,152	949 (II)	757 (IV)	277 (V)	192	88
121	CO_2	1,351	1,035	666 (II)	552 (IV)	205 (V)	93	0
122	Air	1,407	1,122	959 (II)	716 (IV)	339 (V)	144	164
122	Vacuum	1,407	1,252	950 (II)	1,067 (IV)	534 (V)	361	299
122	CO_2	1,407	1,099	899 (II)	622 (IV)	216 (V)	199	164
123	Air	1,768	1,229	1,040 (II)	829 (IV)	441 (V)	268	279
123	Vacuum	1,768	1,388	1,343	880	810	402 (II)	404 (V)
123	CO_2	1,768	1,406	1,403	1,130 (II)	687	412 (IV)	336 (V)
124	Air	1,466	—	—	1,471	—	866	759 (II)

*See "Materials and Methods" for treatments.

†Stages of darkening, represented by Roman numerals, were illustrated in a previous publication (7). Stage II was first appearance of light brown discoloration; Stage IV was brown discoloration of entire piece; and Stage V was brownish-black discoloration, an unappetizing, inedible stage.

only the standard sulfuring, lost ascorbic acid at a considerably higher rate than did any of the other treatments; lot 123, which had the highest sulfurous acid content at the beginning of storage, retained the most ascorbic acid on a proportionate basis, even though the fruit in this treatment was somewhat lower in ascorbic acid after steam blanching and dehydration. The data on lot 124, dried an additional 8 hours to a moisture content of 2.9 per cent, provide evidence that the combination

of low moisture and a relatively high sulfur content is necessary for high retention of ascorbic acid in dehydrated fruit stored at high temperature. Throughout the storage period this lot was consistently higher in ascorbic acid, and at the end of 9 months of storage, this sample was only beginning to exhibit the initial stages of darkening, compared to complete discoloration of all other lots. After 270 days of storage, the loss of ascorbic acid from lot 124 was approximately 66 per cent compared to a loss of 100 per cent for all other samples. Material from lot 124 was not stored at 33 or 65 degrees F, but it may be assumed that losses under those lower temperatures would be very small.

In every comparison of fruit of similar moisture content, the vacuum pack was more effective in ascorbic acid retention than the carbon dioxide pack, whereas both were clearly superior to the air pack in this respect. The data show, however, that pack atmosphere was not as important as the moisture content of the fruit in rentention of ascorbic acid, as shown by comparing lot 124 to all other treatments, regardless of the nature of the pack. The fruit making up lot 124 was sealed in air only; therefore, the difference between the low-moisture, air-packed apples and the other treatments of higher moisture contents, sealed in gas or vacuum, becomes of even greater significance. It would seem that sealing of low-moisture, dehydrated apples (3 per cent moisture or less) in carbon dioxide or in vacuum would offer the possibility of even greater ascorbic acid retention at high temperature storage.

The sulfurous acid contents of the several lots stored at 100 degrees F, as recorded in Table III, show that the low-moisure fruit (lot 124) was clearly superior to all other lots in that approximately 50 per cent of the sulfurous acid was retained after 9 months of storage, whereas the other samples lost from 77 to 100 per cent of initial sulfurous acid in the same period. Other differences among the lots were apparent to the extent that increased sulfuring, and sulfuring plus steam blanching, definitely increased the retention of sulfurous acid during storage, despite relatively small differences in initial sulfur content. In respect to types of pack, vacuum packed fruit retained the most sulfurous acid, CO_2 pack was next in retention, while air packed fruit was poorest in this respect. There was a fairly close relation between the amount of sulfurous acid and the development of discoloration at any given sampling date. Apparently when the sulfurous acid content dropped below 1000 ppm the initial discoloration occurred.

Quantitative sugar and starch analyses on all lots stored at 100 degrees F revealed that the four lots of comparable moisture content (120, 121, 122 and 123 (had similar changes throughout the storage period. Therefore, the figures from these four groups were averaged and compared in Table IV to the sugar and starch determinations of lot 124, the low-moisture fruit. These data indicate a slow, continuous hydrolysis of the relatively low remaining starch in both groups. In the higher-moisture fruit, there was a gradual increase of reducing sugars after 90 days to the end of the storage period when reducing sugars averaged 63 per cent compared to an average of 50 per cent at the beginning of storage. In the low-moisture fruit, on the other hand, this increase in reducing sugars did not take place; a slight decrease was recorded in

TABLE IV—SUGAR AND STARCH CONTENT OF DEHYDRATED STAYMAN WINESAP APPLES SEALED IN AIR AND STORED AT 100 DEGREES F (EXPRESSED AS PER CENT OF DRY WEIGHT)

Days Stored	Reducing Sugars	Non-reducing Sugars	Total Sugars	Starch
		Averages of Lots 120, 121, 122 and 123		
0	49.9	19.9	69.8	1.63
7	49.7	19.7	69.4	
14	49.6	19.0	68.6	
20	48.5	17.9	66.4	
36	50.0	16.0	66.0	
60	49.9	13.8	63.7	
90	50.2	10.0	60.2	1.56
120	52.9	8.8	61.7	
120	53.8	6.9	59.7	
200	57.9	10.9	68.8	1.49
270	62.7	7.3	70.0	1.41
		Lot 124		
0	50.1	20.1	70.2	1.45
14	48.1	16.8	64.9	
20	48.2	15.3	63.5	
90	50.6	13.0	63.6	
150	49.0	21.3	70.3	1.42
270	49.8	23.4	73.2	1.37

the first 20 days of storage, after which time reducing sugars remained around the initial figure of 50 per cent. Non-reducing sugars steadily decreased in the higher moisture fruit; in lot 124, the decrease continued only until the 90th day, after which there was a marked accumulation.

To determine what effect pack atmosphere might have on sugar changes in dehydrated apples stored at high temperature, sugar determinations were made on samples from lot 120, the standard sulfuring treatment, packed in air, CO_2, and in vacuum. These analyses are pre-

TABLE V—EFFECT OF CARBON DIOXIDE, VACUUM AND AIR PACKS ON CHANGES OF SUGARS AND STARCH IN DEHYDRATED STAYMAN WINESAP APPLES STORED AT 100 DEGREES F (EXPRESSED AS PER CENT OF DRY WEIGHT)

Days Stored	Reducing Sugars	Non-reducing Sugars	Total Sugars	Starch
		Air Pack		
0	50.8	22.0	72.8	1.65
90	50.1	8.4	58.5	1.56
150	54.7	4.4	59.1	1.52
200	59.5	7.2	66.7	1.46
270	63.4	6.7	70.1	1.34
		Vacuum Pack		
0	49.4	18.8	68.2	1.64
90	55.4	15.7	71.1	1.67
150	59.9	11.4	71.3	1.47
200	63.0	7.5	70.5	1.45
270	61.4	11.0	72.4	1.47
		CO_2 Pack		
0	50.6	20.0	70.6	1.62
90	56.3	15.5	71.8	1.56
150	60.2	11.6	71.8	1.48
200	63.3	8.1	71.4	1.49
270	64.2	7.2	71.4	1.49

sented in Table V. Reducing sugars increased in all three types of pack atmosphere, but somewhat more slowly during the initial period in the air pack compared to the CO_2 and the vacuum pack. Non-reducing sugars decreased markedly in all packs during the storage period, but with distinct differences among packs. In the air pack this reduction took place rapidly, whereas in the gas and vacuum packs, the decrease in non-reducing sugars was more gradual. Starch determinations indicated a continuous hydrolysis of starch which was somewhat more rapid and continued to a greater extent in the air packed apples than in the gas or vacuum packed fruit.

Discussion and Conclusions

With dehydrated apples, the useful length of storage life under relatively high temperatures, such as 100 degrees F, apparently can be extended (7) far beyond the few days normally expected. The major factors contributing to such longer life appear to be; first and foremost, low moisture content of the dried product; second, a high retention of sulfurous acid, probably aided by high initial sulfur content; and third, a minimum of air in the package, such as found in the use of the vacuum pack.

During storage, chemical changes do occur, including loss of ascorbic acid, loss of sulfurous acid, hydrolysis of starch, increases in reducing sugars and decreases in non-reducing sugars. The carbohydrate changes were noted in spite of a negative peroxidase test after dehydration, but such carbohydrate changes were practically nil at ordinary temperatures (except when peroxidase test was positive), and also were relatively small in material dried to low moisture content (2.9 per cent).

Although chemical changes were not pronounced at lower temperatures during the 9 months of storage, there were significant differences showing somewhat greater changes at 65 degrees than at 33 degrees F, although at both temperatures the major portion of the changes occurred the first 90 days. Differences due to sulfuring treatments were significantly evident at all storage temperatures, but at 100 degrees F, the chemical changes were markedly accelerated and differences in sulfuring and drying treatments exerted greater effects.

No attempt will be made to explain all the chemical changes. It is well known that the presence of oxygen and high temperature result in more rapid loss of ascorbic acid, as shown. High temperatures and time could also have specific effects on carbohydrate changes in the presence of moisture. The loss of sulfurous acid and changes in color of the dried fruit need more investigation to determine the products and factors involved.

From a practical standpoint, it would be interesting to know the maximum moisture content which would be sufficient in combination with vacuum pack to insure commercial shelf life at ordinary temperatures. No doubt, the drying to 3 per cent moisture, plus a vacuum pack, would give much longer life than needed in commercial handling. Further work on the use of blanching in relation to sulfur retention and the rapidity of drying appears important from a commercial point of view.

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The Effects of Nitrogenous Fungicides and Insecticides on the Chlorophyll Content of Apple Leaves[1]

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The use of urea for foliar fertilization of apple trees has become popular with many orchardists. In this connection the question has arisen as to whether nitrogenous fungicides and insecticides also might supply nitrogen directly to the leaves. The experiment described herein was designed to determine if nitrogen is utilized directly from such sprays. The chlorophyll content of the leaves was chosen as a unit for comparison because Boynton, Compton, Fisher and Skodvin (1, 2, 3, 4) have found it one of the best methods for comparing nitrogen in leaves of apple trees. "It is actually better than the nitrogen content of the leaf since the nitrogen has little effect on the vigor of the tree until it increases the chlorophyll" (3).

Dormant 2-year-old McIntosh and Stayman Winesap trees on seedling rootstocks were planted individually in 4-gallon stone glazed crocks in early April 1949. A mixture of two-thirds clay subsoil and one-third quartz sand was used as the substratum with the expectation that the trees would develop with a need for additional nitrogen. Each tree was pruned to a stub 4 to 6 inches in height at the time of planting and two or three shoots were allowed to develop from each stub. They were started in a greenhouse and placed outside on May 19 arranged in a split-plot design with each tree considered as an individual plot. Twenty-four trees of each variety were divided into four replications of six treatments. The five spray materials described in Table I were chosen for comparison with trees not treated.

TABLE I—Spray Materials Tested for Their Effects on Chlorophyll Content of Apple Leaves

Material*	Active Ingredient	Rate Applied Per 100 Gallons	Amount of Nitrogen Per 100 Gallons (Gms)
NuGreen	Urea	5 lbs	975
Fermate	Ferric dimethyldithiocarbamate	1½ lbs	49
Crag 341	2-hepta-decyl-glyoxalidine	1 qt	31
Parathion (25 per cent wettable powder.	Diethyl-paranitrophenyl-thiophosphate	1 lb	5
Phenothiazine (Micronized unconditioned)	Phenothiazine	1 lb	59

*All of these are well known proprietary compounds

Each material was mixed with tap water and 4 ounces of Soya flour per 100 gallons was added as a spreader-sticker. Applications were made with a hand atomizer and all the leaves on each tree were sprayed to run-off under a movable canopy which prevented drift. No other spray materials were used and no injuries associated with spray materials occurred.

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The first applications were made on July 13 at which time the greater part of the foliage was fully expanded. As was anticipated, the trees did not appear in a state of good nutrition and, therefore, should have been receptive to additional nitrogen. Twenty-five comparable leaves on each tree had a single punch 1 square centimeter in area removed from the laminae and collected as a composite sample for chlorophyll determination. The first set of samples was taken immediately before applying the first sprays. A second set of samples was taken from the same leaves 10 days after the first sprays were applied and immediately before the second application on July 23. A third set of samples was taken from the same leaves 10 days after the second application and immediately before the third application on August 3. The fourth and last set of samples was taken from the same leaves on August 13, 10 days after the third application.

In preliminary samplings on trees not used in the experiment it was found that there was practically no variation in chlorophyll content of punches taken from different parts of the laminae of fully expanded leaves. Practically no change in chlorophyll content occurred in leaves sampled four times at 4-day intervals and there was practically no variation in chlorophyll contents of leaves at the base of a shoot in comparison with leaves progressively nearer the tip. The leaf punches were placed in alcohol immediately after removal and the chlorophyll was extracted in the manner described by Compton and Boynton (2). Determination of the chlorophyll concentration was made by means of a Coleman spectrophotometer in camparison with a prepared standard.

The results are summarized in Table II and expressed as milligrams of chlorophyll per 100 square centimeters of leaf area. All of the data were subjected to analysis of variance to determine significant variations. There were no significant differences in chlorophyll content of leaves from trees of the same variety prior to treatment or after treatment on each sampling date. There were no significant differences

TABLE II—Mean Chlorophyll Content Per 100 Square Centimeters of Leaf Area of McIntosh and Stayman Winesap Apple Leaves Given Six Different Spray Treatments and Sampled on Four Dates

Date Sampled	Variety	Spray Treatments: Check (Mgs)	Nu-Green (Mgs)	Fermate (Mgs)	Crag 341 (Mgs)	Phenothiazine (Mgs)	Parathion (Mgs)	Mean (Mgs)	Difference Required for Significance at 5 Per Cent Level (Mgs)
July 13 (Prior to spray application)	McIntosh	2.2	2.3	2 0	2.2	2.3	2.5	2.3	0 56
	Stayman	3 2	2.8	2.8	3.1	3.1	3.0	3 0	
July 23 (10 days after 1st application)	McIntosh	2.2	2.4	2.1	2.2	2.3	2.7	2.3	0.65
	Stayman	3.2	2 8	2.9	3.1	3.2	3.0	3.0	
August 3 (10 days after 2nd application)	McIntosh	2.1	2 2	1.9	2.1	2.1	2.5	2.2	0.61
	Stayman	3.0	2.7	2 8	3 2	3.0	2.8	2.9	
August 13 (10 days after 3rd application)	McIntosh	2.1	2.2	1.9	2.1	2.2	2.3	2.1	0.64
	Stayman	3.0	2.7	2.6	2.9	2.9	2.6	2.8	

in chlorophyll content of leaves from trees of the same variety sampled on the different dates. Leaves of Stayman Winesap consistently contained significantly more chlorophyll than leaves of McIntosh. There were no consistent visible differences in the appearance of the foliage given different treatments and no pathological diseases, such as scab, or insect injuries occurred on any of the trees used in this experiment.

A second set of data was obtained from mature McIntosh and Stayman Winesap apple trees under treatment by the Pathology Division of the Department of Botany[2]. The treatments are described in Table III where it will be noted that check trees were included which did not

TABLE III—NITROGENOUS SPRAY MATERIALS APPLIED ON MATURE McINTOSH AND STAYMAN WINESAP APPLE TREES

Nitrogenous Material	Variety	Sprays Applied Which Included Nitrogenous Material	Rate Applied Per 100 Gallons
Check	McIntosh	No sprays	0
	Stayman	No sprays	0
NuGreen plus sulfur	McIntosh	No sprays	0
	Stayman	Pink, petal fall, first cover*	5 lbs
NuGreen plus Crag 341	McIntosh	No sprays	0
	Stayman	Pink, petal fall, first cover with NuGreen*, Crag 341 as below**	5 lbs, 1 pt
Crag 341	McIntosh	Pre-pink through fifth cover†	1 qt
	Stayman	Pre-pink through fourth cover**	1 qt
Fermate	McIntosh	Pre-pink through fifth cover†	1½ lbs
	Stayman	Pre-pink through fourth cover**	1½ lbs

*First cover spray applied May 23
**Fourth cover spray applied July 21.
†Fifth cover spray applied July 28.

receive any spray throughout the season. The check trees of McIntosh suffered severely from injury by scab, in particular; foliage of the Stayman Winesap checks appeared to be in fair condition. NuGreen was included with wettable sulfur in one treatment and was included with Crag 341 in another treatment. Non-nitrogenous insecticides were included in sprays when required. Duplicate samples of 25 leaf punches were taken from comparable leaves 5 to 7 feet above the ground around the periphery of each tree on August 23. The chlorophyll content of each sample was determined as described previously. The trees were a part of a statistical design which allowed for analysis of variance within each variety and the data are presented in Table IV.

The chlorophyll contents of duplicate samples from each tree were almost always in relatively close agreement, which indicated that the sampling procedure was satisfactory. The chlorophyll content of leaves on McIntosh trees given eight sprays containing Crag 341 was greater to a highly significant degree than the chlorophyll content of leaves from check trees. Leaves from McIntosh trees given eight sprays containing Fermate contained significantly more chlorophyll than leaves from check trees. There was no significant difference in chlorophyll

[2]Through the courtesy of Dr. H. W. Thurston, Jr., Professor of Plant Pathology.

TABLE IV—THE CHLOROPHYLL CONTENT PER 100 SQUARE CENTIMETERS OF LEAF AREA OF DUPLICATE SAMPLES OBTAINED FROM MATURE TREES AUGUST 23, 1949

Replicate	Nitrogenous Spray Material									
	Check (Mgs)		NuGreen Plus Sulfur (Mgs)		NuGreen Plus Crag 341 (Mgs)		Crag 341 (Mgs)		Fermate (Mgs)	
					McIntosh					
1	2.29	2.29	—	—	—	—	3.36	3.47	3.08	3.03
2	2.40	2.76	—	—	—	—	3.19	3.11	2.61	2.46
3	1.92	1.95	—	—	—	—	2.84	3.06	2.68	2.61
4	2.24	2.24	—	—	—	—	3.25	3.11	3.03	2.97
5	2.24	2.24	—	—	—	—	2.61	2.61	2.81	2.87
Mean*	2.3		—		—		3.1		2.8	
					Stayman Winesap					
1	4.24	4.08	3.59	3.59	4.59	4.59	4.49	4.56	3.81	3.96
2	4.33	3.84	4.17	4.17	4.14	4.21	4.24	4.11	4.08	3.87
3	3.43	3.43	3.36	3.36	4.14	4.14	3.90	3.99	3.96	4.21
4	4.36	4.02	3.72	3.72	4.49	4.49	3.47	3.47	3.72	3.72
5	4.09	3.84	3.25	3.14	4.30	4.11	4.36	4.36	3.90	3.81
Mean†	4.0		3.6		4.3		4.1		3.9	

*Difference required for significance at 5 per cent level = 0.5, at 1 per cent = 0.7.
†Difference required for significance at 5 per cent level = 0.4, at 1 per cent = 0.6.

content between leaves of McIntosh trees sprayed with Crag 341 and with Fermate. The chlorophyll content of leaves of Stayman Winesap trees sprayed three times with NuGreen plus seven times with Crag 341 was greater to a highly significant degree than that in leaves of trees sprayed only three times with NuGreen plus sulfur and was significantly greater than that in leaves of trees sprayed seven times with Fermate. Leaves of check trees and trees sprayed seven times with Crag 341 contained significantly more chlorophyll than leaves of trees sprayed three times with NuGreen plus sulfur. There were no other significant differences among treatments.

DISCUSSION AND SUMMARY

Three applications of NuGreen, Fermate, Crag 341, Phenothiazine, and Parathion sprayed on fully expanded leaves of young McIntosh and Stayman Winesap potted trees did not result in significant changes in chlorophyll content as compared with leaves of check trees under the conditions of this experiment. Possibly leaves as nearly mature as those used did not utilize the nitrogen supplied in the foliar sprays or the leaves may have been in a state of nutrition unfavorable for nitrogen utilization as supplied by foliar sprays. Perhaps sampling sooner than 10 days after spraying might have resulted in significant differences which were not apparent 10 days after spraying. Leaves of Stayman Winesap consistently contained more chlorophyll per unit area than McIntosh leaves probably because of their greater thickness.

Leaves of mature McIntosh trees sprayed with two nitrogenous fungicides and leaves of mature Stayman Winesap trees sprayed with four nitrogenous fungicides were sampled only once on August 23. These data showed that eight applications of Crag 341 on one set of McIntosh trees and that eight applications of Fermate on another set

resulted in a higher chlorophyll content of leaves than of those on check trees. The check trees, however, were so severely injured by scab that they could not be considered good comparisons. No significant difference was found between leaves sprayed with the two materials. Periodic sampling throughout the season might have indicated differences not apparent by sampling on August 23 but this procedure was not feasible on these particular trees which were a part of another experiment. Leaves of Stayman Winesap trees not sprayed, those sprayed seven times with Crag 341, and those sprayed three times with NuGreen plus seven times with Crag 341 contained more chlorophyll than leaves sprayed only three times with NuGreen plus sulfur. It is assumed that the sulfur depressed the chlorophyll content of leaves in the latter treatment. The possible effects of NuGreen last applied on May 23 apparently no longer existed by August 23 when the leaves were sampled. The combination of three NuGreen sprays and seven Crag 341 sprays resulted in more chlorophyll per unit area of leaves than of those sprayed seven times with Fermate. There were no other significant differences among treatments on August 23 but this fact does not preclude the possibility of differences earlier in the season. There was definitely no pronounced cumulative effect of the nitrogenous sprays on the Stayman Winesap trees as indicated by the fact that none of the treatments resulted in a significantly higher chlorophyll content than that in leaves of check trees on August 23.

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Growth of the Olive Fruit[1]

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GROWTH of developing olive fruit was studied during the 1946, 1947, and 1948 seasons in connection with a general research program on olive culture in California. The olive is a broad-leaved evergreen, subtropical tree. It differentiates its floral parts in the spring, about 8 weeks preceding bloom, which generally occurs during May. The flowers are of two types: perfect and staminate. They are formed in prodigious numbers, and are borne on inflorescences arising in the axils of the leaves on wood of the preceding year's growth. The staminate flower is similar to the perfect flower except that the pistil is rudimentary. The olive is wind-pollinated and the varieties grown in California are considered to be self-fruitful. The staminate flowers drop soon after bloom, and many of the perfect flowers also drop after varying degrees of development. Fruits still adhering by the first of July generally continue to develop and mature.

The olive fruit is of the drupaceous type (4), with a stony endocarp, a fleshy mesocarp, and a smooth, skin-like epicarp. There are potentially two carpels and four ovules. However, only one embryo and one carpel are usually involved in the development of the ovary because one of the four ovules is fertilized and the other three ovules degenerate (4). The olive fruit is harvested for pickles in California during October or early November, when the surface of the fruit has changed from deep green to straw color. If not picked, however, the fruit will adhere until late winter or early spring before dropping. Olives to be used for oil extraction are generally harvested during December or January.

METHODS

The Manzanillo variety was used in the 1946 tests. Fruit was obtained at approximately 2-week intervals from a mature tree growing at Davis. Collections were made from July 1 to December 1. One hundred fruits were obtained at 8:30 a.m. on each sampling date. They were immediately measured with a vernier caliper at the point of greatest width of the cross diameter. The volume of the fruits was then obtained by displacement of water. At the time of each sampling, another lot of approximately 100 fruits was obtained for making oil-content determinations. A modification of a method used for cottonseed oil content determinations (7) was used.

A very large number of fruits is borne on an olive tree in full production. The number of fruits sampled was proportionately so small that their removal is not believed to have affected the growth rate of the remaining fruits.

A tree of the Mission variety growing at Davis was used for the

[1]The 1946 oil content determinations were made by M. D. Nutting, U. S. Department of Agriculture, Western Regional Research Laboratory, Albany, California. A portion of the 1947 oil content determinations was made by Robert Webster, Chief Chemist, Lindsay Ripe Olive Company, Lindsay, California. Grateful appreciation is expressed for this assistance.

1947 tests. As in the 1946 studies, 100 fruits per sample were used, with collections made at 2-week intervals from June 13 to January 12. Cross-diameter measurements at the point of greatest width were made. The volume was also obtained by displacement of water. In addition, the fresh weight and the dry weight of the fruits were determined. The fruits were dried in an electric oven at 60 degrees C for 2 weeks before obtaining the dry weight. As in 1946, at each sampling date an additional lot of approximately 100 fruits was secured for use in the oil-content determinations. The moisture content of the fruit samples was obtained by subtracting the dry weight from the fresh weight. The oil content was calculated as a percentage of both the fresh weight and the dry weight. The grams of oil per fruit were determined by multiplying the dry weight of the sample by the oil percentage of the dry weight. The "dry matter other than oil" was calculated by subtracting the oil from the total dry weight. The oil in the fruit was retained in the sample during the drying process as it does not volatilize unless the drying temperature is somewhat over 100 degrees C.

In the 1948 measurements, the Mission, Manzanillo, and Ascolano varieties were used. The fruit was taken from mature trees growing in a variety collection at Davis. One hundred fruits per sample were collected at 2-week intervals from June 29, 1948 to January 24, 1949. The fruit shriveled severely, however, after about November 20, due to low temperatures and drying winds. The data collected after November 16 were therefore discarded. Fruit samples were taken at about 8:30 a m, and volume measurements were made by displacement of water. The fresh weight of the 100-fruit sample was taken. The fruit was then dried in an electric oven at 60 degrees C for 2 weeks, when the dry-weight measurements were obtained. No oil content determinations were made on the 1948 collections.

Results

1946:—Table I and Fig. 1 show that the Manzanillo olive fruit exhibits the cyclic growth behavior typical of the common drupaceous fruits, other than the almond (1), when size or fresh-weight measurements are used (2,5,6,8). In Fig. 1, it is seen that when fruit volume

TABLE I—Growth Measurements and Oil Content of Manzanillo Olive Fruits, Davis, California, 1946 (Full Bloom–May 23)

Date of Sampling	Growth Measurements		Oil Content (Per Cent)	
	Diameter (Mm)	Volume* (cc)	Fresh Weight	Dry Weight
Jul 1	8.4	0.5	0.1	0.4
Jul 15	11 4	1.4	1.0	3 0
Jul 29	12.4	1.5	0.9	2.4
Aug 12	13.6	2.0	1.9	4.8
Aug 23	13.7	2.0	3.1	8.4
Sep 9	14.1	2.1	6.8	19.0
Sep 28	16.0	2.9	8.6	23.5
Oct 5	15.8	2.9	10.9	30.3
Oct 19	16.9	3.4	14.4	38.3
Nov 2	16.5	3.7	15.2	38.2
Nov 15	17.0	3.7	17.4	42.3
Dec 1	17.1	3.8	17.4	43.9

*Per fruit, based on an average of 100 fruits.

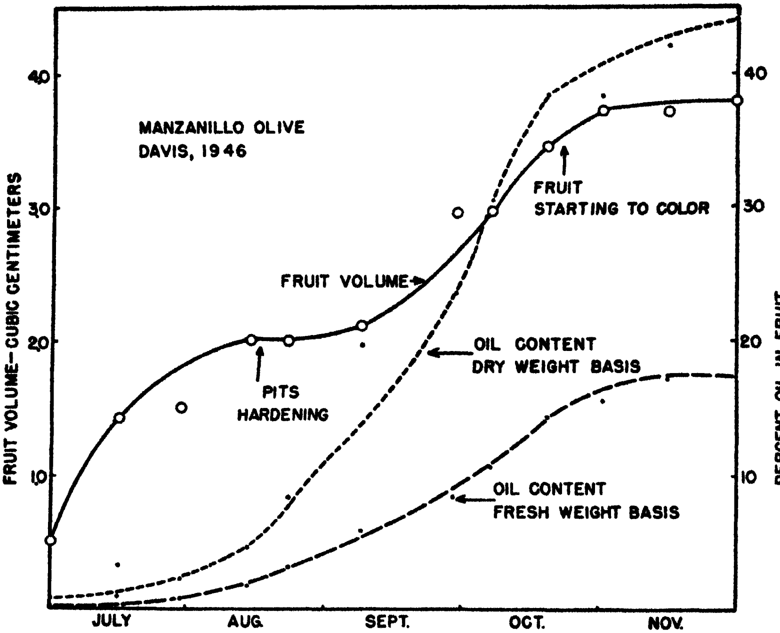

FIG. 1. Fruit volume and oil content of the Manzanillo olive during the 1946 growing season at Davis.

was used as a measurement of growth the first rapid size increase terminated about August 15, a date coinciding approximately with the beginning of the hardening of the pit. After a period lasting about 3 weeks, rapid increase in volume was again resumed. This continued until about the first of November, when further size increase was not made until at least December 1, at which time measurements were discontinued. Coloring of the fruit (development of a cherry red color) coincided approximately with the end of the last period of rapid growth.

The oil content determinations of the Manzanillo fruit during 1946 showed very little synthesis of oil until about August 1. At that time oil production was initiated at a fairly uniform rate until about the first part of November, when further increase in oil content failed to appear.

1947:—The 1947 results with the Mission variety are given in Table II and Figs. 2, 3, and 4. Cyclic growth is again evident in the measurements of volume, cross diameter, and fresh weight. The curve for oil production in Fig. 3, based on actual amounts, shows some slight cyclic tendency. The curve for "dry matter other than oil", however, shows no periodicity. The curve for moisture in Fig. 3, based on actual amounts rather than on percentage, shows a marked cyclic behavior following somewhat the pattern for the curve of the fresh weight of the fruit. During November, December, and January, there appeared to be a gradual decrease in moisture in the fruit. This was nullified by a steady increase in "dry weight other than oil" and a sharp rise in oil

TABLE II—GROWTH MEASUREMENTS OF MISSION OLIVE FRUITS, DAVIS, CALIFORNIA, 1947 (FULL BLOOM–MAY 8)

Date of Sampling	Cross Diameter (Mm)	Weight Per Fruit (Gms)		Volume Per Fruit (Cc)	Moisture Content		Oil Content (Per Cent)		Oil Per Fruit (Gms)	Dry Matter Other Than Oil Per Fruit (Gms)
		Fresh	Dry		Grams	Per Cent	Fresh Weight	Dry Weight		
Jun 13	5.6	0.22	0.08	0.18	0.14	63.6	0.7	1.7	0.001	0.079
Jun 27	8.9	0.70	0.22	0.89	0.48	68.6	0.6	1.9	0.004	0.216
Jul 11	11.0	1.37	0.50	1.28	0.87	63.5	0.7	2.2	0.011	0.489
Jul 25	11.6	1.59	0.61	1.45	0.98	61.6	1.0	2.6	0.016	0.594
Aug 8	12.4	1.89	0.75	1.72	1.14	60.4	2.9	7.0	0.053	0.697
Aug 22	13.0	2.08	0.78	1.93	1.30	62.6	4.0	10.0	0.078	0.702
Sep 8	13.5	2.34	0.92	2.20	1.42	60.7	6.8	17.5	0.161	0.759
Sep 19	13.6	2.32	0.93	2.20	1.39	60.0	7.4	17.7	0.166	0.764
Oct 2	13.8	2.42	0.92	2.30	1.50	62.0	8.3	21.8	0.201	0.719
Oct 17	15.4	3.21	1.16	3.10	2.05	63.8	10.1	30.0	0.348	0.812
Oct 30	16.0	3.60	1.27	3.52	2.33	64.8	12.1	33.6	0.427	0.843
Nov 18	15.4	3.33	1.28	3.20	2.05	61.6	12.1	31.9	0.408	0.872
Dec 1	16.8	3.43	1.40	3.30	2.03	59.2	14.3	33.0	0.462	0.938
Dec 15	15.9	3.58	1.70	3.40	1.88	52.6	18.2	37.8	0.643	1.057
Dec 29	16.0	3.59	1.52	3.45	2.07	57.6	21.1	44.3	0.673	0.847
Jan 12	16.3	3.84	1.93	3.75	1.91	49.8	——	——	0.855*	1.075

*Assuming per cent oil was the same as on December 29.

TABLE III—GROWTH MEASUREMENTS OF OLIVE FRUITS, DAVIS, CALIFORNIA, 1948 MISSION, MANZANILLO, AND ASCOLANO VARIETIES (FULL BLOOM–JUNE 5)*

Date of Sampling	Mission			Manzanillo			Ascolano		
	Volume (Cc)	Fresh Weight (Gms)	Dry Weight (Gms)	Volume (Cc)	Fresh Weight (Gms)	Dry Weight (Gms)	Volume (Cc)	Fresh Weight (Gms)	Dry Weight (Gms)
Jun 29	0.02	0.21	0.06	0.20	0.20	0.06	0.14	0.14	0.04
Jul 13	0.05	0.52	0.17	0.55	0.57	0.17	0.51	0.55	0.15
Jul 27	1.04	1.11	0.34	0.95	1.02	0.32	1.41	1.44	0.37
Aug 10	1.32	1.44	0.53	1.30	1.37	0.44	2.21	2.32	0.76
Aug 24	1.61	1.75	0.69	1.68	1.77	0.60	2.95	3.02	0.94
Sep 7	1.97	2.13	0.84	1.97	1.96	0.68	3.99	4.07	1.28
Sep 21	2.20	2.35	0.89	2.39	2.46	0.82	4.21	4.27	1.32
Oct 5	2.13	2.26	0.87	2.56	2.61	0.89	4.65	4.55	1.46
Oct 19	2.70	2.84	1.13	3.20	3.22	1.03	5.98	5.86	1.80
Nov 2	2.92	3.03	1.18	3.71	3.68	1.22	5.92	5.80	1.78
Nov 16	3.25	3.37	1.42	3.50	3.44	1.18	6.50	6.37	2.02

*Figures given are per fruit based on an average of 100 fruits.

content during December and January. As with the Manzanillo variety in 1946, oil production started about August 1. In the Mission, it increased in amount at a fairly steady rate until December and January, when there was a sharper rise in oil content.

1948:—While cyclic growth was again found in the 1948 measurements, the second growth period was not so prominent as it was in the preceding 2 years. This is shown in the curves for volume measurements in Fig. 5. In comparing the growth rate of the three varieties, Ascolano, Manzanillo, and Mission, it was found that the Ascolano fruit, which is characteristically much larger than either the Manzanillo or Mission, made a considerably more rapid increase in size during the first growth period than did the other two varieties. The Manzanillo and Mission fruits grew at practically the same rate during period I, although the Manzanillo continued growth for a somewhat longer time than did the Mission. In the third growth period, the fruits of the

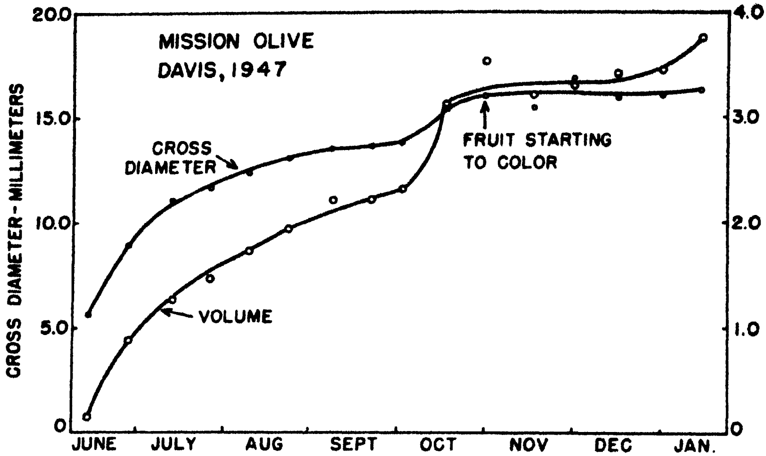

FIG. 2. Fruit volume and cross diameter of the Mission olive during the 1947 growing season at Davis.

Manzanillo variety had a higher rate of growth than did those of the Mission in reaching their characteristically greater size. During the third growth period, Ascolano fruits increased in size at about the same rate as the Manzanillo.

DISCUSSION

The profitable production of olives for pickles in California is dependent to a great extent on obtaining large-sized fruit. From this study it is apparent that it would be to the grower's benefit to delay harvest until the fruit had completed the increase in size which occurs just before the fruit starts to color. This pronounced size increase was completed in the Manzanillo variety at Davis in 1946 by October 15. It was completed in the Mission variety at Davis in 1947 by the third week in October.

The unusually cool weather conditions during April and May, 1948, over most of central California, delayed the olive blooming period about 2 weeks at Davis. On account of this late start, the final increase in size of olive fruits in 1948 was not completed until about the middle of November. Unfortunately for growers who waited later than this for maximum fruit size, frosts and drying winds in late November severely shriveled the fruit and made it unsalable for use as table olives. The fruit then had to be disposed of as the less profitable oil olives.

The usual harvest period for pickling olives in California occurs from the first of October to mid-November depending upon the variety. Undoubtedly, therefore, much of the fruit is harvested after this period of "final swell". Growers who make a practice of early harvesting, however, may not be obtaining the maximum size possible from their fruit. Factors other than fruit size, of course, may determine the optimum time to harvest the crop. These are largely the processing character-

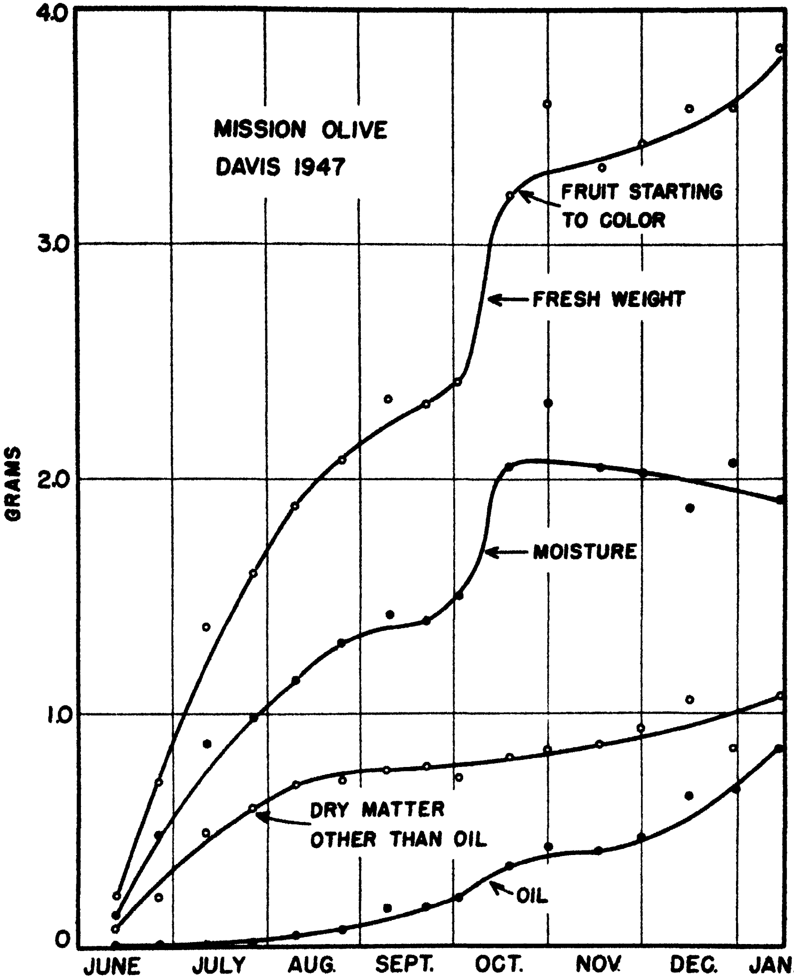

Fig. 3. Fresh weight, moisture, oil, and dry matter other than oil of Mission olives during the 1947 growing season at Davis; weight per fruit, based on average of 100 fruits.

istics of the variety, which necessitate harvesting at certain stages of maturity to make a satisfactory product. As shown in Fig. 3, the sharp increase in fruit size just prior to fruit coloring in October is accounted for largely by increased moisture in the fruit. There is no particularly large increase in oil or "dry weight other than oil" at this time. For the grower to obtain the full benefit of this size increase it would appear necessary to keep the trees supplied with readily available water during this period of accelerated size increase. In fact, Hendrickson and Viehmeyer (3) have found with the olive that when the soil moisture drops to the "permanent wilting percentage" it is reflected in a reduced rate

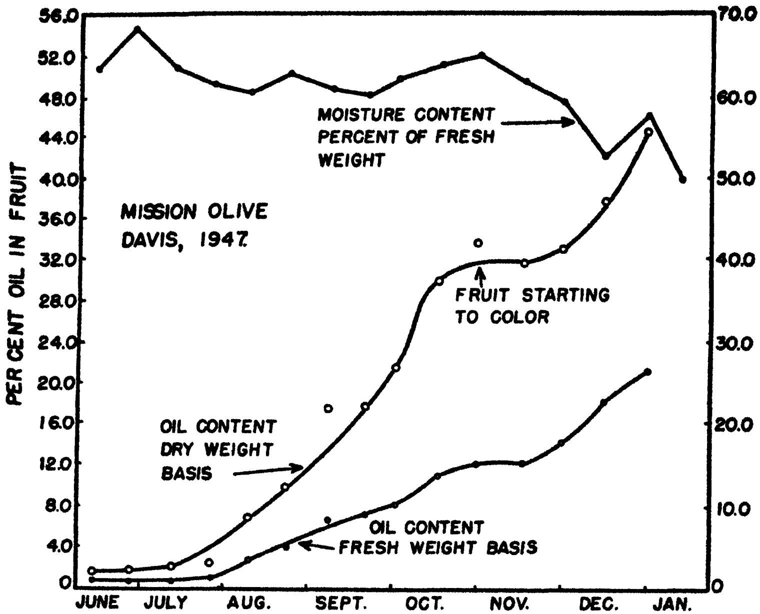

FIG. 4. Moisture content and oil content of Mission olive fruits during the 1947 growing season at Davis.

of size increase, which results in a smaller-sized fruit at maturation even though subsequent irrigations are given.

As the Mission is the leading olive variety in California for the producton of olive oil, the data for oil content in this variety are interesting to study. The curve in Fig. 3 showing oil content agrees with the experience of olive growers in that the oil content increases steadily into midwinter. Very few olives are harvested for oil in California before the middle of December, and probably the bulk of the oil olives is picked during January. This increase in oil content in the olive during December and January, coming after the fruit has attained the expected full size of Period 3, results in a growth curve unlike the other drupe fruits. Rather than leveling off at the end of Period 3, as do most drupe fruits, the Mission olive, at least, showed an additional rise in the growth curve due to this accumulation of oil. This difference might be expected since the olive is the only one of the commercially-grown drupaceous fruits which accumulates oil in the mesocarp and which adheres to the tree with continuing maturity until the following blooming period is almost reached. In winters of abnormally low temperatures, however, such as that of 1948–49, the fruits shrivel to such an extent that this final increase in size would be obscured.

Fruits of two of the commercial olive varieties grown in California (Sevillano and Ascolano) are characteristically much larger in size than the other two commercial varieties (Mission and Manzanillo). Ac-

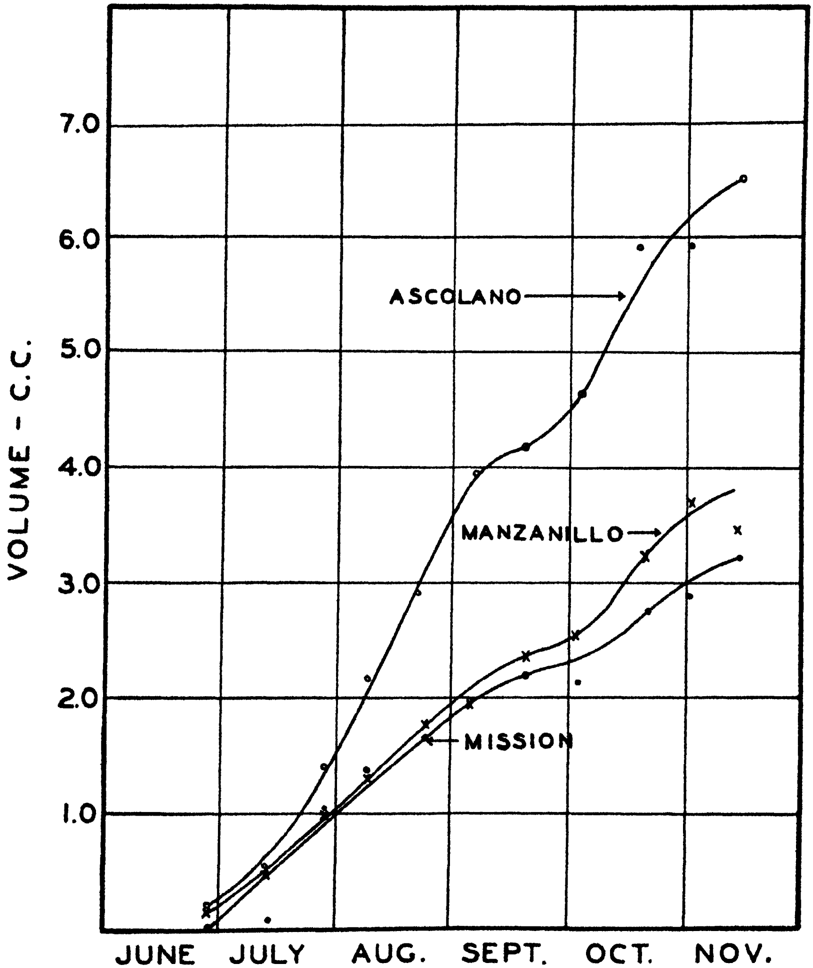

FIG. 5. Fruit volume of three olive varieties during the 1948 growing season at Davis.

cording to the measurements obtained in 1948, this greater size, at least in the Ascolano variety, is attained during the first period of growth.

SUMMARY

1. Diameter, volume, and oil content measurements of the Manzanillo olive were made during the 1946 season from July 1 to December 1 at 2-week intervals. Diameter, volume, fresh-weight, dry-weight, and oil content measurements of the Mission olive were made during the 1947–48 season from June 13 to January 12 at 2-week intervals. Volume, fresh-weight, and dry-weight measurements were also

taken for the Mission, Manzanillo, and Ascolano varieties at 2-week intervals from June 29 to November 16 during the 1948 season.

2. Growth of the olive fruit appears to have the same cyclic behavior typical of other fleshy drupaceous fruits when diameter, volume, or fresh-weight measurements are used. In these studies an initial period of rapid growth was followed by a period of reduced rate of growth, which, in turn, was followed by a period of rapid increase in growth rate. However, the Mission olive, in the 1947 measurements, differed from the other drupaceous fruits in that, in addition to the three usual growth periods, there was an additional flat period followed by another period of accelerated size increase which was due to oil accumulation occurring in December and January.
3. In 1946 and 1947, the third period of growth, in which the fruit increased markedly in size, occurred during October just before color started to develop in the fruit. In 1948, when the blooming period was about 2 weeks later than usual, the termination of the third growth period occurred during mid-November. This was immediately followed by frosts and drying winds which shriveled the fruit severely.

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Form and Composition of Cherry Fruits (Prunus avium and P. cerasus) Following Fall Applications of 2,4–Dichlorophenoxyacetic Acid and Naphthalene Acetic Acid[1]

By H. B. Tukey and C. L. Hamner, *Michigan State College, East Lansing, Mich.*

Growth regulating substances have been used to delay the blossoming of fruit trees (4, 6, 7, 14). The results reported in the present paper describe the responses from a fall application of a mixture of 2,4–dichlorophenoxyacetic acid and naphthalene acetic acid made to trees of sour cherry *(Prunus cerasus)* and sweet cherry *(Prunus avium)* for the purpose of delaying bloom against spring frost.[2]

Materials and Methods

The orchard to which the application was made was planted in 1928. It is located near Empire, Michigan, 3 miles from the east shore of Lake Michigan, and 20 miles west of Traverse City, in the commercial cherry producing section of Michigan. The site is a frost pocket into which cold air settles, so that until 1947 the orchard had borne little or no fruit, in spite of the fact that it is reported to have blossomed heavily for a number of years. The trees are large and vigorous except for the lower and inside limbs which are weak as the result of close planting and resultant shading. The main planting is of the Montmorency variety of sour cherry, with a few trees of the Windsor and Schmidt varieties of sweet cherry.

On October 17, 1946, approximately 500 trees in this orchard were sprayed with a mixture of commercial formulations[3] of naphthalene acetic acid at 100 ppm and 2,4–dichlorophenoxyacetic acid at 16 ppm. The material was applied with a commercial "speed-sprayer" in a water spray using a total of 5,000 gallons. The trees were well covered with spray except for occasional top branches. Half of the orchard was left untreated. The orchard had been sprayed with 2–3–100 Bordeaux mixture prior to harvest and with 3–4–100 Bordeaux mixture as a post-harvest spray, made the last of August.

The weather was clear and relatively warm for the season of the year (60 to 65 degrees F) and continued seasonal until November 5, when freezing temperatures and a sleet storm occurred. Winter temperatures were normal for the region. Spring was later than usual, with no severe frost damage. Trees blossomed heavily and bore fruit.

Observations were made of leaf fall, blossoming, and tree and fruit growth and development. Analyses of fruit from both treated and un-

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[1]Journal paper number 1090 of the Michigan Agricultural Experiment Station.

[2]The authors are indebted to H. D. Hootman, Michigan State College, C. H. Hemstreet, District Horticultural Agent, Traverse City, and Magness Frederickson, Northport, Michigan, for their cooperation and assistance.

[3]"Apple-set" and "2,4–Dow" respectively, manufactured by the Dow Chemical Company, Midland, Michigan.

treated trees were made of total sugars as invert sugars, moisture, and titratable acid.[4]

Results

Sour Cherries

On October 17, 1946, 33 days after the trees were sprayed, the leaves on both treated and untreated trees were still green. The older leaves on sprayed trees were somewhat folded upward along the mid-rib, some of them approaching an angle of 90 degrees with the transverse axis.

The younger leaves and those which were less mature, such as those inside the trees or in positions which delayed their maturity, showed additional response, leaf blades were bent upward, except for the tips, which were bent downward. Petioles and leaf blades showed twisting. There were suggestions of occasional small necrotic areas on small twigs and branches.

Following freezing temperatures and a sleet storm on November 5, the leaves fell from untreated trees, but adhered 3 to 5 days beyond this date on sprayed trees.

The trees blossomed full in the spring of 1947. Unsprayed trees blossomed on June 4. Sprayed trees blossomed full on June 9 to June 11, or 5 to 7 days later. The unevenness in time of blossoming was characteristic of sprayed trees in contrast to the uniformity of unsprayed trees. The blossoms on the most vigorous branches were those which were least delayed, and the blossoms on the weakest branches were those most delayed. The general effect was striking, in which the sprayed portion of the orchard was still not in bloom when the adjacent rows of unsprayed trees were white with blossoms.

Examination of the twigs, showed small necrotic areas and brown fleckings either in or under the bark. This condition was most severe on weak and shaded branches and was entirely absent from strong, vigorous branches. There was occasional bud killing on weak wood. On both treated and untreated trees the fruit set, although the set seemed less heavy on treated than on untreated trees.

On June 26, just after "shuck" (toral tube) fall, it was noticed that the fruits on treated trees were markedly elongate and pointed. The shucks were persistent and because of their reddish color gave a reddish cast to the treated portion of the orchard seen from a short distance. Some of the fruit on the sprayed trees was larger than that on unsprayed trees, and some was smaller. The smaller affected fruits were longer and more pointed than were the larger ones. Blossoms which typically would have dropped, and fruit with abortive seed also adhered.

On July 31, 1947, when the fruit was ripe for commercial harvest, the general characteristics of tree, fruit, and foliage were similar to those previously noted, but some were more pronounced and some less

[4]Acknowledgment is made to Dr. E. J. Benne, Department of Agricultural Chemistry, Michigan State College, for the analyses and calculations.

so. For example, the shaded and weaker portions of the treated trees now showed considerable injury. Browning was noticeable in the pith and xylem of spurs. Some branches were entirely dead, not unlike the results from winter injury or from injury by an oil spray. In contrast, vigorous portions of treated trees showed no such injury.

In color, the fruit on sprayed trees was light red, perhaps due to the delayed bloom and consequent later date of maturity associated with a fewer number of days from full bloom (11). In addition, however, some fruits were amber-color and translucent. The pointedness of the fruit on sprayed trees was by this time less marked due to the fact that the fruit of the Montmorency variety typically changes from elongate to rounded oblate at maturity (10). The stony pericarp was now observed to be elongate and sharply pointed and the receptacle was much enlarged.

The vascular system within the fruit was strongly developed, so that the fruit seemed firmer. In many instances the vascular system appeared as a light-colored mesh network from which the soft portions of the flesh of the fruit could be easily separated, leaving the network intact. In severe cases, the bundles were dark brown and discolored, and the flesh nearest the pit was greenish or brownish and strongly adherent to it.

The strong development of the vascular system extended also into the pedicel of the fruit so that it was held tenaciously to the tree. In many cases it was not possible to harvest the fruit by stripping it from the tree without the stems, because the pit and vascular system were so firmly attached that the soft flesh would tear away, leaving the pit and stem on the tree.

The fruits from treated trees seemed more meaty and sweeter. Refractometer[5] readings showed an average of 19.65 per cent total solids for fruit from treated trees as compared to 16.5 per cent from untreated trees (Table I). Chemical analyses of the fruit revealed

TABLE I—REFRACTOMETER READINGS OF MONTMORENCY CHERRY FRUITS FROM TREES SPRAYED WITH NAA AND 2,4-D THE PREVIOUS FALL

Treated	Refractive Index	Soluble Solids (Per Cent)
Sprayed	1 3629	19.65
Sprayed (light colored fruit)	1.3576	16.5
Untreated	1.3577	17.25

higher moisture content, higher acidity, and lower sugar content for the fruit from treated trees, suggesting that the higher total solids may have been associated with stronger vascular development as discussed above.

On September 4, 1947, many dry blossoms and partially developed fruit were still adherent to trees which had been treated. Observations were also made at this time on fruits which had not been harvested and

[5]Acknowledgment is made to W. F. Robertson, Michigan State College, for the readings.

which were still hanging on the trees. The fruits on sprayed trees were amber red, watery, stringy, and without sweetness or flavor. In contrast, fruits on unsprayed trees were dark red, sweet and well-flavored. Chemical analyses agree with these observations, showing higher sugar content and lower moisture content for the fruits from unsprayed trees (Tables I and II).

TABLE II—ANALYSIS OF MONTMORENCY CHERRY FRUITS FROM TREES SPRAYED WITH NAA AND 2,4-D THE PREVIOUS FALL (DRY WEIGHTS)

Treatment	Pits Plus Seed* (Per Cent)	Moisture† (Per Cent)	Total Sugar as Invert Sugar† (Per Cent)	Titratable Acid As Ml 0 1N Acid/Gm†
At Time of Commercial Harvest—July 31				
Sprayed	9.07	82.70	10 48	2 14
Unsprayed	8 52	81.34	12.17	2.01
Fruits Remaining 35 Days After Commercial Harvest—September 4				
Sprayed	12.10	91.22	4.52	1.12
Unsprayed	11 17	85 78	7.62	1 48

*Values based on weight of entire fruit.
†Values based on weight of fleshy pericarp.

SWEET CHERRIES

The effect of the fall application of naphthalene acetic acid and 2,4-dichlorophenoxyacetic acid to Windsor and Schmidt cherries was in general similar to the effect on the Montmorency sour cherry as described in the preceding paragraph. However, they were in general of greater intensity. Further, the effect was greater on the Schmidt variety than on the Windsor. The folding of leaves, the curvatures of leaves and petioles, the delay in blossoming, the injury to buds, and twigs, the persistence of schucks (toral tube), flowers and fruits with abortive embryos, and the elongation and pointedness of both pits and fruits were characteristic.

The elongate shape and the points or tips on both fruit and pit were much more pronounced on the sweet cherry than on the sour cherry (Fig. 1). This characteristic shape was most evident in the early development of the fruit and was less noticeable as the fruits increased in transverse diameter. Pits were over twice as long as wide.

The receptacle also was more affected than with the sour cherry, in some cases becoming twice as wide as is typical, thick and fleshy, and remaining green until fruit harvest.

The vascular system was strongly developed, often appearing as brownish streaks through the flesh of the fruit. The flesh nearest the pit was often a hard, green or brown mass of tissue which adhered tenaciously to the pit. This condition, in addition to a strong vascular development into the pedicel, made it almost impossible to separate the stem from the fruit. If the fruit was held in one hand and the basal end of the pedicel in another, the pedicel would break before separating from the fruit. In the most severe cases, the fruits were tough, fibrous, and insipid.

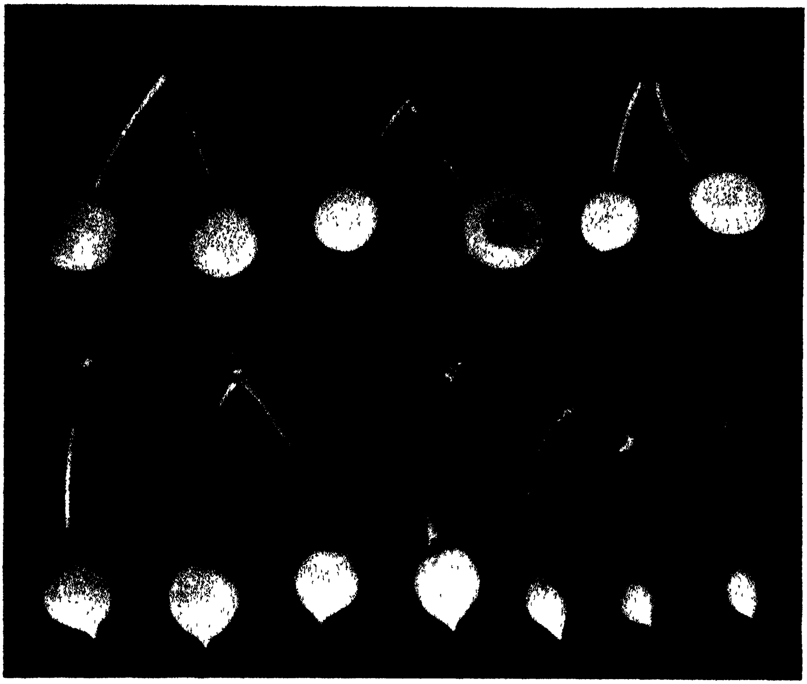

FIG. 1. Effect of a fall application of naphthalene acetic acid and 2,4-dichlorophenoxyacetic acid on the shape of cherry fruits, showing oval shape and small tip development on Montmorency sour cherries (above) and marked elongation and pronounced tip on Schmidt sweet cherries (below).

Discussion

The delay in blossoming of cherry trees from the fall applications of growth regulating substances reported in this paper have seemed associated with injury to the plant. Zimmerman and Hitchcock (4) report killing of some flower buds of sour cherry following summer and early fall applications which delayed spring blossoming from 14 to 19 days. Mitchell and Cullinan (7) also noted injury to peach buds following spring treatments with growth regulators whereby leaf buds but not flower buds were retarded. Marth, Havis, and Batjer (6) observed dead buds following late summer, fall and mid-winter applications of growth regulators to peach trees in which blossoming was delayed 2 days. They also observed a retarding effect from fall removal of entire leaves and portions of leaves. The results reported in the present paper show a definite association between the severity of injury and the degree of retardation of blossoming. Further, the weakest blossom buds and the buds on weakest wood were the buds most retarded, while the vigorous buds on strong wood were least affected.

Although the blossoming of cherries was delayed by fall application of growth regulating substances, perhaps the more significant effects

were those on leaves, twigs, flowers and developing fruit. Many attempts have been made to prevent preharvest dropping of peaches and other stone fruits by spraying during the same season the fruit is developing, but with little or no success. The fact that application made the fall of the preceding season had such a marked effect on not only abscission but also on firmness and composition, suggests further study and refinement of the method. Further, while most of the effects that have been observed are not of a nature that enhance the value of the fruit or that are valuable in fruit production, there are some phases that should be explored. Among these are the stronger adherence of the pedicel to the fruit, alteration in chemical composition of fruit, reduction of early-season drop of fruit, and alteration of the time of harvest.

It is of interest that both the sweet and sour cherry are relatively less responsive to applications of growth regulators during spring and summer than are the apple and the pear (1, 3, 5, 8, 9). Unpublished data (12) show that vigorous young Montmorency cherry trees may be sprayed in spring and mid-summer with several growth regulators at relatively high concentrations with little effect upon the growth or subsequent development of the plant or its parts. Yet applications made in late summer and fall, as reported in this paper, produce profound effects. The facts suggest that there are critical or sensitive points in the growth of a plant so far as effects of growth regulators are concerned; and that in the case of the cherry, applications made in fall may have a striking affect upon carpel development which is reflected in the development of the fruit during the following season. The studies by Watson (13) on modifications of bean leaves as a result of treatment with 2,4–D are interesting in this connection, they show a delayed expression of the effect of a growth regulator, associated with the stage of development of a leaf at the time the treatment is made. The possibilities are suggested of studies of the effect of growth regulators in fruit bud development, on form of fruit, on the development of the flesh, on cling and non-cling characters, on embryo development and on the development of one plant part in relation to another.

Summary

An application of a mixture of naphthalene acetic acid and 2,4–dichlorophenoxyacetic acid made to sweet and sour cherry trees on October 17, resulted in:

1. Characteristic curvatures of foliage and delayed abscission the same season.
2. Injury to twigs, buds and spurs.
3. Delayed blossoming the following spring.
4. Persistence of the "shucks" (toral tube) and delayed abscissions of abortive flowers and abortive fruits.
5. Elongate fruit with pointed apices.
6. Enlarged receptacle.
7. Strong vascular development within both the fruit and the pedicel.

8. Strong adherence of the pedicel to the fruit.
9. Adherence of the flesh to the pit and immaturity of the flesh near the pit.
10. Lighter color of fruit and delay in maturity.
11. Change in chemical composition of fruit, notably increase in moisture content and titratable acidity and reduction in sugar content.

Whether the responses were the result of naphthalene acetic acid or 2,4–dichlorophenoxyacetic acid alone or in combination, or both, is not known.

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Controlled Growth of Fig Fruits by Synthetic Hormone Application

By Julian C. Crane, *University of California, Davis, Calif.*, and René Blondeau, *Shell Oil Company, Inc., Modesto, Calif.*

The external application of synthetic growth regulating substances to plants has been demonstrated to induce diverse growth and differentiation effects. Among the most noteworthy effects are the delay of abscission in prevention of preharvest drop of fruit, the production of fruits without pollination, bud inhibition of plant materials in storage, the selective killing of weeds, and root production on cuttings of species which ordinarily are slow or sparce root producers. Of particular interest here, however, are the effects of growth regulating substances on the rate of maturation of various kinds of fruit before removal from the plant.

While applications of plant growth regulators have resulted in several instances in somewhat earlier fruit maturation, no marked changes in the developmental pattern of the fruit, of the magnitude reported here, have taken place. Allen and Davey (1) observed that preharvest "hormone" sprays applied to Bartlett pears resulted in a more rapid softening and the fruit "was therefore more advanced in maturity when harvested" than unsprayed control fruit. Gerhardt and Allmendinger (7) found that when Delicious apples and Bartlett pears treated with a "hormone" spray were permitted to hang on the trees much beyond the optimum harvest season, post-maturation processes occurred more rapidly than in comparable lots of unsprayed fruit. Christopher and Pieniazek (4) reported that attached McIntosh apples which had received preharvest "hormone" sprays exhibited better red color development than did the unsprayed fruit. Batjer and Thompson (2) found that 2,400 ppm of naphthaleneacetic acid applied to foliage of McIntosh fruiting spurs resulted in 69 per cent ripe fruit at time of harvest, whereas only 2 per cent of the fruits were ripe on adjacent unsprayed spurs. Mitchell and Marth (12) reported that tomatoes produced with the aid of growth regulating substances often developed faster and matured from 4 to 10 days earlier than did pollinated fruit. This earlier maturation effect was usually confined to the first and sometimes the second clusters on the vine.

As a continuation of investigations initiated in 1947 to determine the possibility of promoting parthenocarpic fruit development in the Calimyrna fig by the use of growth regulators (5), several additional compounds were tested during the season of 1948, among which were 2,4,5–trichlorophenoxyacetic acid (hereafter referred to as 2,4,5–T) and its isopropyl ester. As previously reported (3), the application of these materials to unpollinated but pollen-receptive syconia resulted in a phenomenal hastening of fruit development, the details of which will be discussed here.

Materials and Methods

Since this investigation was conducted in a commercial orchard near Merced, California and provisions by the owner had been made for

pollination, it was necessary, in an attempt to induce parthenocarpic fruit, to prevent cross-pollination with the male or caprifig. In order to accomplish this, all branches bearing fruit that were to be sprayed with growth regulators were covered with white muslin bags on June 24 to exclude the pollen-carrying fig wasp, *Blastophaga psenes* L. Caprifigs to supply pollen for the control fruit, as well as the remainder of the orchard, were suspended in the Calimyrna trees at 3- to 4-day intervals during the period from June 25 to July 5. When the branches were treated on July 1, the muslin bags were removed and the spray application quickly made. The bags were replaced and left until July 12, when the caprifigs had become dry and devoid of wasps.

It should be pointed out here that enlargement of the Calimyrna fig takes place until it is about 30 mm in diameter when, if not cross-pollinated, it loses its green color and abscisses. Most of the figs in a given orchard in a particular locality are receptive to pollination within a 2 to 3 weeks' period and caprifigs to supply pollen are placed in the trees at periodic intervals throughout this time. Figs at the proximal ends of the new shoots are receptive first followed in turn by figs at the median and distal portions.

A water solution of 2,4,5-T and an oil emulsion containing the isopropyl ester of 2,4,5-T were applied with a small hand spray gun. These materials in concentrations of 10, 25, 50, 75, and 100 ppm were sprayed thoroughly on the fruits, foliage, and shoots. Five replicate branches for each concentration of spray material were treated.

At the time of spray application each branch bore at least five figs, the fruits located at the proximal ends of the current season's shoots having been macroscopically evident for approximately 45 days. Fruits born on the median and distal portions of the shoots were progressively younger and smaller in size.

Cross-diameter measurements with a vernier caliper were made of both caprified (pollinated) control and sprayed (parthenocarpic) figs at approximately weekly intervals from the time the fruits were about 5.0 mm in diameter until maturity. Figs on 10 control branches on each of 10 trees were measured, whereas measurements were made of fruits on five replicated branches for each concentration of the two growth regulators used.

Results and Discussion

The curve of growth, A in Fig. 1, shows that unpollinated Calimyrna fig syconia sprayed with 25 ppm of 2,4,5-T on June 30 were mature 15 days later on July 15. Figs which received the spray application grew at an average rate of 1.25 mm per day during the ensuing 15-day period as compared with the control fruits, represented by line C in Fig. 1, which grew at an average rate of only 0.23 mm per day. As a result of this rapid rate of increase in size, the length of the growing period was shortened to approximately 60 days instead of the average 120-day period necessary for normal fruit development to maturity. The fruits thus formed were comparable in size and color to pollinated fruits that matured on September 9. Although completely devoid of

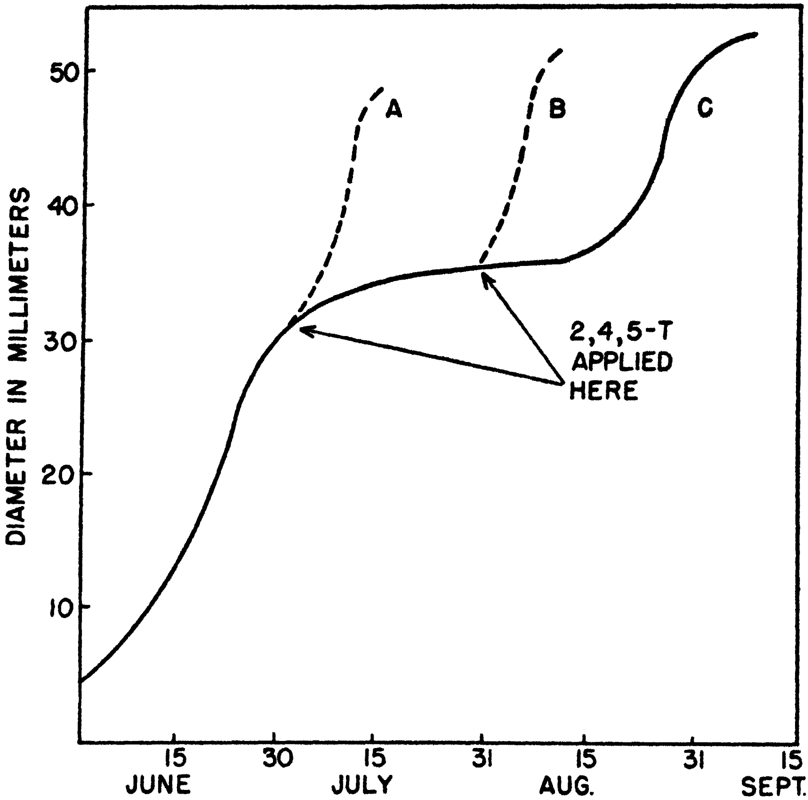

FIG. 1. Curves of growth, as measured by diameter, of unpollinated (A) and pollinated (B) Calimyrna fig fruits sprayed with 25 ppm of 2,4,5-trichlorophenoxyacetic acid as compared to pollinated but unsprayed control fruits (C). Curves represent the average diameters of the four proximal-most figs on current season's growth.

achenes ("seeds"), the chemically-induced parthenocarpic fruits were well-filled with pulp and were quite palatable.

As far as rate of fruit growth and ultimate size attained were concerned, results very similar to the above were obtained with the other concentrations of 2,4,5-T employed. For example, 15 days after the sprays were applied at 10, 25, 50, 75, and 100 ppm they had induced, respectively, 56, 64, 69, 72, and 65 per cent mature fruits of approximately normal size. Even the smallest distal-most figs on the shoots, although they did not reach normal size, were yellow in color and possessed a texture like that of mature fruits. Comparable results were obtained with identical concentrations of the isopropyl ester of 2,4,5-T.

A concentration of 10 ppm of 2,4,5-T or the ester resulted in a moderate to severe leaf chlorosis which persisted throughout the season. The higher concentrations produced increasingly severe in-

jury, and death of the sprayed branches occurred at the 75- and 100-ppm levels about 1 month after treatment. It is believed that the injurious effect of the spray was accentuated due to the fact that the branches were covered with muslin bags for about 3 weeks. In some instances, unbagged branches adjacent to those sprayed received small quantities of spray as drift, and, although the fruit matured similarly to those in the experiment, there was little or no leaf injury, even with spray concentrations of 100 ppm. Apparently there was an insufficient quantity of the spray deposited on the leaves to cause injury but enough applied to the fruit to stimulate development.

The significance of this radically accelerated parthenocarpic fruit development was recognized and the question logically arose as to what might be the response of normally pollinated Calimyrna figs to spray applications of 2,4,5–T. This material, in water solutions of 25 and 50 ppm, was sprayed therefore on the fruits and foliage of five branches for each concentration.

The curve of growth, B in Fig. 1, represents the diameter increase of pollinated fruits that were sprayed on July 29. Here, again, fruit growth was greatly accelerated so that maturity was attained 13 days after the spray was applied or 29 days before the maturity of pollinated but unsprayed control fruit. For the 13-day period following the spray application, fruits so treated increased in diameter at an average rate of 1.27 mm per day as compared to 0.07 mm per day for the control fruits. Mature figs obtained in this manner possessed external and internal characteristics similar to mature control fruits with the exception that the achenes were not so fully sclerified. Moderate to severe leaf chlorosis, and in some cases death, occurred about one month after spray application.

Similar results to those obtained with unpollinated and pollinated Calimyrna figs were realized with fruits of the Mission variety sprayed with 20 ppm of 2,4,5–T on August 17 at Winters, California. This variety normally develops its fruits parthenocarpically and, although the figs contain numerous achenes, the latter do not have embryos. The curve of growth, A in Fig. 2, shows that rate of growth was stimulated by the spray application to such an extent as to bring about maturity 17 days in advance of unsprayed control fruits. Here, likewise, the empty achenes were not sclerified to the extent as were achenes in the control fruits.

The degree of leaf injury accompanying the spray application in this case was not consistent. Leaves on some of the shoots were severely chlorotic while on others there seemed to be no apparent damage in spite of the fact that fruits on these shoots matured as rapidly as did fruits on shoots where injury occurred. Observations made with regard to leaf injury as a result of spray application on both the Calimyrna and Mission varieties seemed to indicate that the later in the season the spray was applied the less was the resultant leaf injury.

Referring to Fig. 1, it is noted that the ultimate fruit size attained increased progressively the later in the season maturity took place. Assuming the seasonal fluctuation of carbohydrates in the fig tree follows a pattern similar to that which has been reported for the apple

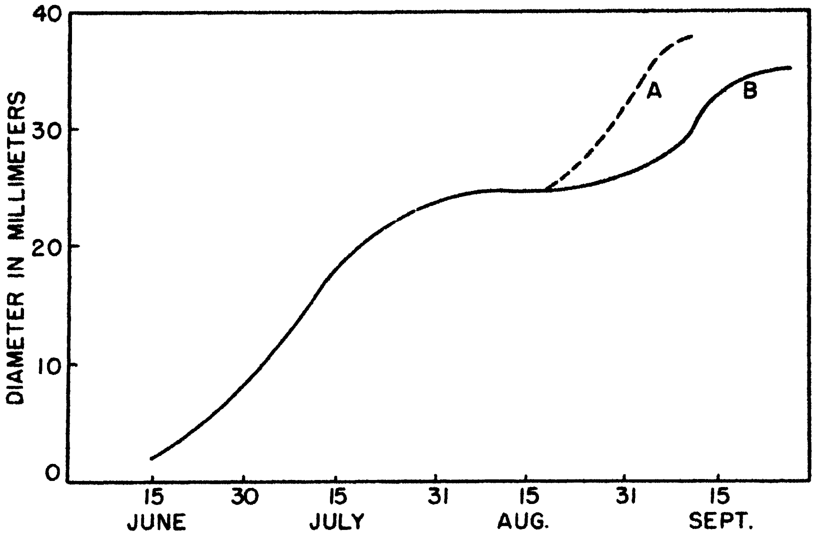

FIG. 2. Curves of growth in diameter of Mission figs sprayed with 20 ppm of 2,4,5-trichlorophenoxyacetic acid on August 17. Sprayed fruits (A) and unsprayed control fruits (B).

(9) where the carbohydrate content increases from May to September, the relationship between ultimate fruit size and time of maturity may be explained on this basis. Since shoot growth of the fig continues until about July 1, those figs which matured on July 15 were competing with shoot and leaf growth for carbohydrates, a factor which undoubtedly accounted for their smaller size. As the carbohydrate supply was gradually increased by the assimilatory activity of the leaves, fruits that matured on August 11 and September 9 were progressively larger at maturity. No explanation can be offered as to why Mission fig fruits that matured on September 10 as a result of a 2,4,5-T spray application were larger than control fruits that matured on September 27 (see Fig. 2).

Figs. 1 and 2 show that growth of the fig fruit, as measured by diameter increase, takes place in three distinct periods. This double sigmoid type of growth curve, which is typical also of most drupaceous fruits, has been the subject of speculation by various investigators, particularly in regard to the cause for the occurrence of the period of retarded rate of size increase. In a previous article (6) data were presented which indicated that cyclic growth of the fig fruit was controlled by variation in supply or activity of a hormone produced within the fruit itself. Data accompanying the present paper substantiate this hypothesis. In fact, together with the work of van Overbeek (15), the mechanism of flower formation and fruit development would appear to be directly controlled by hormones.

Auxin has been shown by Gustafson (8) to control the growth of the carpels, while van Overbeek *et al* (16) reported ovule development

to be dependent upon hormone supply. Although diverse growth effects may result from applications of various synthetic hormones to living tissues, the fundamental role of these substances remains to be demonstrated. The rapid rate of fruit development reported here, as brought about by applications of 2,4,5-T, might be based upon one of several plant responses which auxins have been demonstrated to induce. Although Mitchell *et al* (11), working with bean plants, found that various growth regulating substances induced an acceleration in the rate of starch hydrolysis, a chemical change that takes place in the ripening of certain kinds of fruits, this was not the case with the Calimyrna fig since iodine tests at intervals throughout the growing period indicated no starchy reserve present. On the other hand, as demonstrated by van Overbeek (17), tissues contain considerable amounts of inactive auxin precursor which can be quickly made available as active auxin. It is possible that the application of 2,4,5-T to fig syconia activated the inactive auxin precursor which, in turn, was responsible for the accelerated rate of fruit development. However, since 2,4,5-T itself is an auxin, it is more probable that this material caused an increase in the rate at which food materials were mobilized into the fruit from other parts of the tree as has been shown by other investigators working with bean plants (10, 13, 14). On July 12, or 12 days after the application of 2,4,5-T, the sprayed fruits contained 67 per cent total sugars on a moisture free basis as compared to unsprayed fruit which contained 27 per cent total sugars. Three days later, or on July 15, when the fruits were judged as mature, treated fruits contained 87 per cent total sugars whereas the unsprayed control fruits contained 29 per cent sugars on a moisture free basis. Since a simultaneous investigation with indolebutyric acid showed that this material had to contact the fruit before parthenocarpic development occurred, probably the seat of activity of 2,4,5-T was also in the fruit. Apparently the application of 2,4,5-T raised the auxin level to a point high enough to cause a rapid mobilization of stored food reserves. In the unsprayed control fruits, under the influence of the normal hormone level, mobilization of food materials occurred much more slowly over a period of about 2 months during which the rate of fruit diameter increase was very slow.

Summary

Spray applications at concentrations of 10, 25, 50, 75, and 100 ppm of 2,4,5-T or its isopropyl ester to unpollinated but pollen-receptive syconia of the Calimyrna fig induced parthenocarpic development and maturity about two weeks after treatment. Thus, the length of the fruit growth period was shortened to 60 days instead of the usual 120-day period necessary for normal fruit development to maturity. The fruits thus formed were comparable in size and color to mature, pollinated fruits and, although completely devoid of achenes ("seeds"), they contained a normal amount of sugar, were well-filled with pulp and quite palatable.

Applications of 2,4,5-T to pollinated Calimyrna figs as well as par-

thenocarpic fruits of the Mission variety, likewise, greatly accelerated the rate of fruit development.

Moderate to severe leaf chlorosis accompanied the use of these materials at concentrations of 10 ppm. The higher concentrations produced increasingly severe injury, and death of the sprayed branches occurred at 75- and 100-ppm levels about 1 month after treatment.

Data presented substantiate the hypothesis in a previous paper that cyclic growth of the fig fruit is controlled by variation in supply or activity of a hormone produced within the fruit itself.

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Effects of 2,4–Dichlorophenoxyacetic Acid and 2,4,5–Trichlorophenoxyacetic Acid on Citrus Fruit Storage[1]

By Wm. S. Stewart, *University of California Citrus Experiment Station, Riverside, Calif.*

In January, 1947, a study was initiated to determine the effects of 2,4–dichlorophenoxyacetic acid (2,4–D) and of 2,4,5–trichlorophenoxyacetic acid (2,4,5–T) preharvest-drop sprays (9,10) on citrus fruit storage. This was a cooperative project between the Research Department of the California Fruit Growers Exchange, Ontario, and the Division of Plant Physiology of the University of California Citrus Experiment Station, Riverside.

Citrus storage may be considered as the interval between fruit harvest and delivery to the consumer. For oranges this interval may be, at the most, 8 to 9 weeks. This allows 1 week for cleaning, grading, wrapping, and packing, 4 weeks' storage at a temperature of 35 degrees F for precooling, 2 weeks at 45 degrees F for refrigerated boxcar transit, 1 week in unopened boxes at room temperature, and 1 week for the display of unwrapped fruit on a rack at room temperature. A test conducted according to the procedure outlined above is referred to as a "commercial storage test".

Under certain market conditions, grapefruit has been stored for more than a month before packing, but the storage of this fruit is generally similar to that of oranges. In contrast, lemons may be harvested while still green in color, and stored for as long as 5 to 6 months. Commercially, lemons are usually stored at temperatures of 58 to 60 degrees F, and at 85 to 88 per cent relative humidity. Because of the long storage period, the emphasis of these studies has been on lemons.

The storage tests reported here were made on citrus fruit from groves in southern California, and were of two general classes: (a) storage of fruit from trees sprayed with 2,4–D or 2,4,5–T before harvest for control of preharvest drop; and (b) storage of fruit treated with 2,4–D after harvest. In all experiments the 2,4–D or 2,4,5–T was used as formulated in weed-killing preparations

[1]Paper No. 602, University of California Citrus Experiment Station, Riverside, California.

Appreciation is expressed to the Sherwin-Williams Company for supplying lanolin emulsion containing butyl ester of 2,4–D, and for butyl ester formulations of 2,4–D and 2,4,5–T used in the experiments reported here.

Mr. R. D. Nedvidek and Mr. J. L. Baker, of the California Fruit Growers Exchange Research Department, conducted the tests at Ontario, California, where fruit-storage facilities are available. They, together with the writer, inspected the fruit and interpreted storage results (1,2,8). They also aided in selecting the type of groves to be treated and the quality of fruit necessary for the tests. This project was initiated and directed by the writer, who established the field plots.

Treatment of Fruit With 2,4–D and 2,4,5–T Sprays Before Harvest

Lemons.—Lemons are the only citrus fruits that are held in storage for a prolonged period. Commercially, the length of the storage period depends upon the color grade of the fruit ("yellow", "silver", "light green", "green", and so on), and the greener the fruit, the longer the storage time before decay and breakdown. In storage, the citrus fruit may develop what is known as "black button" (Fig. 1), the "button"

Fig. 1. Storage lemons. Left, healthy fruit showing green button and no decay; right, diseased fruit showing black button and Alternaria decay.

referring to the calyx. At harvest time this "button" is usually green, but during storage it may turn black. This condition indicates that internal Alternaria decay will soon occur, if it is not already present (5).

The first lot of the 1948 crop of lemons was from a Latin-square-designed plot in a grove near Corona, California. Four treatments, including the control, were applied on 40 trees each. The trees were vigorous, and the fruit was of good quality. Drenching water sprays containing 8 ppm 2,4–D or 2,4,5–T were applied on April 8, 1948. The 2,4–D was applied as the triethanolamine salt and as the isopropyl ester. The 2,4,5–T was applied as the butyl ester. The first pick subsequent to spraying was on May 7, 1948; the second was on June 16, 1948.

The fruit was stored up to 162 days at 58 to 60 degrees F and 88 per cent relative humidity. After storage, a greater proportion of green

buttons and a smaller proportion of black buttons and of internal Alternaria decay were found in the fruit of all color grades from trees sprayed with either 2,4–D ester or 2,4,5–T than in the fruit from non-sprayed trees. Usually, there was also less external decay in fruit from the sprayed trees. The data (Table I) show that in most cases the isopropyl ester of 2,4–D was more effective than the triethanolamine salt in inducing these responses. The butyl ester of 2,4,5–T, however, was four to five times as effective as the isopropyl ester of 2,4–D in reducing black buttons on "light-green", "green", and "dark-green" lemons; it was not quite this effective on "yellow" and "silver" lemons, although here, also, it was more effective than 2,4–D.

TABLE I—EFFECT OF PREHARVEST SPRAYS OF 2,4-D AND 2,4,5-T ON DEVELOPMENT OF BLACK BUTTONS, EXTERNAL DECAY, AND INTERNAL ALTERNARIA DECAY OF EUREKA LEMONS IN STORAGE

Date of Harvest and Color Grade of Lemons at Beginning of Storage	Preharvest Spray Treatment of Trees (April 8, 1948)*	Number Fruits Stored	Storage Period (Days)	Percentage of Fruits Showing		
				Black Buttons	External Decay	Internal Alternaria Decay
May 7, 1948 (first pick):						
Yellow	None (control)	512	115	57.0	2 15	5.47
	2,4-D (T)	540	115	30 9	1 48	1 11
	2,4-D (I)	232	115	31 3	0 43	0.00
	2,4,5-T (B)	573	115	22.3	0.70	1.22
Light green	None (control)	902†	162	87 91	3 85	1.23
	2,4-D (T)	814	162	35 13	7 62	4.05
	2,4-D (I)	910	162	24.29	2 20	2 75
	2,4,5-T (B)	1,213	162	7 75	1 65	0.82
Green	None (control)	1,102	162	41 65	12.25	5.35
	2,4-D (T)	606	162	26.40	1 65	1.81
	2,4-D (I)	685	162	23 36	1 46	1.17
	2,4,5-T (B)	975	162	4.51	0 72	0.41
June 16, 1948 (second pick):						
Silver	None (control)	120	120	61.67	13.33	6.67
	2,4-D (T)	86	120	50 00	16 28	4.65
	2,4-D (I)	124	120	45.97	1.63	5.65
	2,4,5-T (B)	146	120	29.45	2 72	4 11
Light green	None (control)	820	120	49 39	3.66	4 63
	2,4-D (T)	570	120	50 00	4.91	4.39
	2,4-D (I)	628	120	35 51	2.23	2.07
	2,4,5-T (B)	388	120	14.69	3.87	1.29
Green	None (control)	756	120	49.21	2.38	2.65
	2,4-D (T)	639	120	28.79	1 41	1.25
	2,4-D (I)	797	120	28.36	0.63	0.63
	2,4,5-T (B)	753	120	8 63	1 33	0.13
Dark green	None (control)	669	120	23.92	0 30	1.05
	2,4-D (T)	600	120	17 00	0.00	0.67
	2,4-D (I)	460	120	18 48	0.00	0.65
	2,4,5-T (B)	654	120	2.60	0.92	0.00

*2,4-D (T) = 8 ppm 2,4-D water spray as the triethanolamine salt; 2,4-D (I) = 8 ppm 2,4-D as the isopropyl ester, 2,4,5-T (B) = 8 ppm 2,4,5-T as the butyl ester.

†After 115 days' storage, 51.3 per cent of this lot of fruit had black buttons, and 1.88 per cent showed external decay. More than 30 per cent of the black-button fruit, when cut, showed indications of the presence of Alternaria, which probably would have developed into decay within 2 weeks. These fruits were discarded after cutting and are not included in the value given for Alternaria decay.

Six other lots of 1947 fruit from trees sprayed with 2,4–D were late summer lemons, and all but one lot were of exceptionally poor quality. For this reason, and because of the small number of fruits in each sample, the results were not so consistent as the data pre-

sented in Table I. It appeared, however, that the "green" lemons from trees sprayed with 8 ppm (or less) 2,4–D in August, September, or October had an increased resistance to black button and to Alternaria decay. Results similar to those in Table I were also obtained with "yellow", "silver", or "green" lemons of good quality from trees sprayed with 2,4–D added to oil-water emulsions used for pest control. In this instance the oil-emulsion spray consisted of 2 per cent medium, soluble spray oil to which the isopropyl ester of 2,4–D had been added at the rate of 4 ppm acid equivalent, on the basis of the final volume of the prepared spray emulsion.

Combination of all the results available for the various color grades of fruit in this study of the effects of preharvest sprays on lemon storage yields 61 comparisons between samples of treated and nontreated fruit. In 50 cases the treated fruit had a lower percentage of black buttons than the nontreated, and in 4 there were no differences. In 41 cases there was less external decay in the treated fruit, and in 4 there were no differences. In general, lemons from trees sprayed with 2,4–D or 2,4,5–T had an increased storage life in comparison with fruit from nonsprayed trees, because of a reduction in black buttons and external decay.

Tests of juice availability did not show any appreciable differences between treated and nontreated lemons. Compared with nonsprayed fruit, the sprayed fruit, especially that sprayed with 2,4,5–T, had an increased storage life without loss of available juice.

Although adequate data are not yet available, there is some indication that a reduction in black buttons may be obtained on lemons harvested any time within 5 to 6 months after 2,4–D spraying.

Oranges:—On January 10, 1947, an experimental plot was established in a Washington Naval orange grove near Highgrove, California. A drenching water spray containing 25 ppm 2,4–D was applied to some of the trees; others were left nonsprayed. By harvest time, April 21, 1947, fruit drop had been reduced 60 per cent as a result of the spray, and fruit samples were selected at random from the sprayed and nonsprayed trees for a commercial storage test, omitting the usual fungicidal borax wash. From these samples, sound fruit free of visible defects and having green buttons were selected for wrapping and packing in shipping boxes upon which covers were then nailed as for actual shipment. The two packed boxes contained fruit of the same size and number (338).

After 8 weeks (56 days) of storage, the fruit treated with 2,4–D showed strikingly fewer black buttons and rind defects (pitting, spotting, and aging), but more external decay, than the control samples (Table II). The juice quality of both samples was good. Decay probably would have been reduced if the fungicidal wash used in packing houses had been given prior to storage. It should be pointed out, however, that a sample of only 338 fruits is inadequate; therefore, unless substantiated by further tests, the results are not considered conclusive.

A storage test was also conducted with Valencia oranges. Trees in a grove near Spadra were sprayed with 8 ppm 2,4–D on June 19,

1947. By harvest time, October 7, 1947, fruit drop of sprayed trees had been reduced 32.3 per cent, compared with that of nonsprayed trees. On this date, fruit samples were taken for storage. Only sound fruit free of blemishes was selected. The 5-week (35-day) storage period consisted of 2 weeks at 35 degrees F (precooler temperature), then 2 weeks at 40 to 45 degrees (car temperature), followed by 1 week at 70 to 80 degrees (room temperature).

After storage at these temperatures, the 2,4–D-sprayed fruit showed no appreciable differences from the nonsprayed fruit in external decay, rind defects (pitting, spotting, or aging), or black buttons. The loss of fruit in any of these categories was relatively slight (Table II).

TABLE II—EFFECT OF PREHARVEST SPRAYS OF 2,4-D ON DEVELOPMENT OF BLACK BUTTONS, EXTERNAL DECAY, AND RIND DEFECTS IN WASHINGTON NAVEL AND VALENCIA ORANGES AND IN GRAPEFRUIT DURING STORAGE*

Trees	Preharvest Spray Treatment	Number Fruits Stored	Storage Period (Days)	Percentage of Fruits Showing			
				Black Buttons	External Decay	Rind Defects†	
						Slight	Severe
Washington Navel orange	None (control)	338	56	38.17	1.18	66.17	3.62
	2,4-D, 25 ppm	338	56	0.88	9 76	38.76	3.55
Valencia orange‡	None (control)	903	35	5 87	0.11	15.50	3.10
	2,4-D, 8 ppm	903	35	5.20	0.33	13.95	1.44
Grapefruit§	None (control)	959	105	87.59	24.19	6.99	1.98
	2,4-D, 8 ppm	900	105	57 67	9.44	5.22	4.44
	2,4-D, 16 ppm	1,117	105	30 83	5.28	4.29	1.70

*Orange plots established in cooperation with Dr. L. J. Klotz, grapefruit plot, with Dr. E. R. Parker.

†Including pitting, spotting, and aging.

‡Fruit showing severe granulation and internal decline after storage: control, 14.5 per cent; 2,4-D-sprayed, 4 8 per cent.

§Black-button fruit showing internal Alternaria decay after storage: control, 3.44 per cent; 2,4-D-sprayed (8 ppm), 1.56 per cent and (16 ppm) 0.90 per cent.

The fruit was then cut for observation of severe granulation and internal decline (4). The percentage of nonsprayed fruit having this category of defects was 14.5, compared with 4.8 per cent for the 2,4–D-sprayed. Slight granulation and internal decline were not recorded. These figures can only be accepted as indicative of the need for further data on this possible effect of 2,4–D on granulation of Valencia oranges. Although the sample size was sufficiently large in this test, a single experiment is entirely inadequate to establish the validity of a response of this type.

Grapefruit:—A storage test was made on grapefruit from Arlington Heights, California. On April 29, 1947, certain trees in a Latin-square-designed plot were given drenching water sprays of 8 or 16 ppm 2,4–D. By harvest time, September 3, 1947, these sprays had reduced fruit drop 46 per cent and 48 per cent, respectively, in comparison with nonsprayed trees. All the fruit from this plot was used in the storage test.

Prior to storage, the grapefruits were washed with 0.5 per cent soap solution, then treated with a 1.25 per cent water solution of soda ash, and waxed with a solution containing 0.75 per cent of California

Fruit Growers Exchange Water-Wax No. 22. This Water-Wax is a combination of paraffin and carnauba wax with emulsifying and spreading agents. The culls were discarded, and the washed, treated, and waxed samples were stored at a temperature of 58 to 60 degrees F and at a relative humidity of 85 to 88 per cent. Each sample consisted of 15 boxes of fruit. The fruit was removed from storage at frequent intervals for inspection. Decayed fruit was discarded, and the remainder was returned to the storage rooms.

Table II presents the storage data comparing nonsprayed fruit with that sprayed with either 8 or 16 ppm 2,4–D. The sprayed fruit showed a reduced amount of external decay, aging, and black buttons throughout storage. There was also a decrease in internal Alternaria decay, as shown by cutting and examination of the black-button fruit after storage.

After 15 weeks' (105 days') storage, the fruit from trees sprayed with 16 ppm 2,4–D was rated the best with regard to firmness, color, and general appearance; that from trees sprayed with 8 ppm 2,4–D was rated next best; and the nonsprayed fruit was rated the poorest of the three lots.

Treatment of Fruit With 2,4–D After Harvest

Another approach to the effect of 2,4–D on citrus fruit storage is in its application to the fruit in the packing house before storage. This use of 2,4–D was suggested by the effects of similar applications of 2,4–D on bananas, pears, and apples (7).

Lemons:—In the summers of 1946 and 1947, very limited preliminary tests were made to determine the effect of dipping green lemons in a 2,4–D solution before storage. The results were not encouraging, but since the trials were considered inadequate, in October, 1947, a more comprehensive series of tests was planned for the 1948 lemon harvest.

On May 17, 1948, subsequent to washing and waxing, as described above, both "light-green" and "green" lemons from trees not sprayed with 2,4–D were dipped for 2 minutes in a lanolin emulsion containing either 500 or 1,000 ppm acid equivalent of the butyl ester of 2,4–D. These fruits were then stored at 58 to 60 degrees F and 88 per cent relative humidity.

One sample of washed and waxed "green" lemons was exposed for 69 hours to the vapor of the isopropyl ester of 2,4–D by placing 10-cm petri dishes containing 5 ml of ester on the bottom of each section of a storage box, covering the dishes with a hardware-cloth guard, and placing the fruit above the dishes. During the exposure time, this fruit was held at 58 to 60 degrees F and 88 per cent relative humidity in a storage room separate from that containing control, nonvapor-treated fruit. After exposure, the treated lemons were placed in the storage chamber with the nontreated fruit. Storage time includes the period of exposure to 2,4–D vapor.

The first inspection was made after 115 days' storage at 58 to 60 degrees F and 88 per cent relative humidity. The data presented in

Table III show that 1.88 per cent of the control, nondipped "light-green" lemons had external decay, and 51.3 per cent had black buttons. Examination of the black-button fruit for internal Alternaria decay showed that more than 30 per cent had indications of decay which would have developed within 2 weeks, although not decayed at this time. In contrast, all the 2,4–D-treated samples of "light-green" fruit were sound and firm and showed no black buttons or decay.

TABLE III—EFFECT ON EUREKA LEMONS OF PRESTORAGE IMMERSION IN LANOLIN-2,4-D EMULSION OR EXPOSURE TO 2,4-D ISOPROPYL ESTER VAPOR

Color Grade of Fruit	Prestorage Treatment	Number Fruits Stored	Storage Period (Days)	Percentage of Fruits Showing		
				Black Buttons	External Decay	Internal Alternaria Decay
Light green	None (control)	902	115	51.30	1.88	—*
		902	162	87 91	3.85	1 28
	Lanolin emulsion dip:					
	500 ppm 2,4-D	158	162	1.90	0.00	0 00
	1,000 ppm 2,4-D	166	162	3 01	0.00	0 00
Green	None (control)	1,102	162	41.65	12 25	0 53
	Lanolin emulsion dip:					
	500 ppm 2,4-D	166	162	0 00	0 00	0.00
	1,000 ppm 2,4-D	166	162	0.00	0.60	0.00
	2,4-D isopropyl ester vapor (exposure, 69 hours)	164	162	23 78	1.22	0.00

*More than 30 per cent of the black-button fruit, when cut, showed indications of the presence of Alternaria, which probably would have developed into decay within 2 weeks.

Even after 162 days of storage, only 3.01 per cent of the "light-green" fruit dipped in 1,000 ppm 2,4–D had black buttons, and none had Alternaria decay, in comparison with 87.91 per cent with black buttons and a large amount of Alternaria (as indicated above) for the nondipped fruit (Table III). No visible decay developed in the dipped fruit, compared with 3.85 per cent in the nondipped. The "green" lemons dipped in either 500 or 1,000 ppm 2,4–D solutions failed to develop a single fruit with black button or Alternaria decay after 162 days of storage. Visible decay was 0.60 per cent for the dipped fruit, compared with 12.25 per cent for the nondipped.

Vapor treatment of "green" lemons with isopropyl ester of 2,4–D for 69 hours at the beginning of storage (Table III) also reduced black buttons and Alternaria decay, as well as visible decay, in comparison with nontreated fruit. The reduction was much less than for the dip treatment. It is possible, however, that continuous exposure to the vapors would be just as effective as the dip application.

In addition to the dip and vapor treatments with 2,4–D, 500 ppm 2,4–D as the butyl ester was added to the Water-Wax emulsion. Lemons were waxed with this preparation in the usual manner and stored as described. The storage results (Table IV) show that in all color groups there was a remarkable reduction in percentage of fruit with black buttons, Alternaria decay, and external decay. This method of 2,4–D application appears to be as effective as the lanolin-emulsion dip treatment in reducing decay, if not more so.

Oranges:—One preliminary storage test with Valencia oranges

TABLE IV—PERCENTAGE OF EUREKA LEMONS SHOWING BLACK BUTTONS AND DECAY AFTER 120 DAYS' STORAGE FOLLOWING TREATMENT WITH COATING OF WATER-WAX-2,4-D EMULSION

Color Grade of Fruit	Prestorage Treatment	Number Fruits Stored	Percentage of Fruits Showing		
			Black Buttons	External Decay	Internal Alternaria Decay
Silver	None (control)	120	61.67	13.33	6.67
	Water-Wax-2,4-D emulsion	87	12.64	1.15	1.15
Light green	None (control)	820	49.39	3.66	4.63
	Water-Wax-2,4-D emulsion	413	2.66	1.69	0.00
Green	None (control)	756	49.21	2.38	2.65
	Water-Wax-2,4-D emulsion	484	1.45	0.41	0.00
Dark green	None (control)	669	23.92	0.30	1.05
	Water-Wax-2,4-D emulsion	121	2.48	0.00	0.00

treated with Water-Wax containing 500 ppm 2,4–D indicated a reduction in black-button formation compared with that of nontreated fruit. Apparently, Valencia oranges are similar to lemons in this response to 2,4–D.

DISCUSSION

In view of the marked increase in storage life of fruit from trees sprayed with 2,4,5–T, compared with those sprayed with 2,4–D, it seems probable that 2,4,5–T will be an even more desirable compound than 2,4–D for treatment of harvested citrus fruits.

These tests suggest various other means of applying 2,4–D and 2,4,5–T to citrus fruit during storage. In lemon storage houses, the 2,4–D or 2,4,5–T vapor might be introduced directly into the circulating air stream. This possibility is being tested by the Research Department of the California Fruit Growers Exchange at Ontario, California. The 2,4–D or 2,4,5–T might also be applied by spraying the storage room walls or by impregnating the paper wrapping or even the shipping boxes. These, of course, are at present only possibilities, and the likelihood of their use will depend on developments from tests now in progress. The use of 2,4–D or 2,4,5–T sprays on trees to reduce preharvest drop of fruit apparently also caused a reduction in black-button formation and internal Alternaria decay. This seems remarkable, considering that some of the weak fruit which would have ordinarily dropped off, as it did from the nonsprayed trees, was harvested from the sprayed trees.

Alternaria is considered the most important cause of decay of California lemons, with the possible exception of Penicillium. The Alternaria fungus may be found in or on the buttons of even very young fruit in the orchard (3). The usual fungicides and disinfectants have failed to control the fungus except at concentrations which also injure the fruit (5).

The effectiveness of 2,4–D and 2,4,5–T in reducing black buttons and Alternaria decay is not difficult to understand if one assumes that they delay maturity of the abscission layer between the fruit and the stem. When this layer matures, its cell walls weaken and the stem may completely separate from the fruit as in fruit drop, or the fruit may remain loosely held and stem die-back may result (6). Since citrus

fruits in California are harvested by clipping the stem just above the fruit, a short segment of stem remains on the fruit when it is put into storage. It is thought that maturation of the abscission layer in stored fruit results in the death of this stem segment. As a consequence of this weakness in the protective armour of the fruit, Alternaria decay may enter and grow from the button into the fruit interior. Thus, presumably as a result of delaying maturation of the abscission layer by 2,4–D or 2,4,5–T application, the fruit button is maintained in a living condition for a longer period after harvesting than otherwise, and black button and resulting Alternaria decay are thereby reduced.

Summary

Lemons and grapefruit from trees in southern California orchards sprayed with 2,4–dichlorophenoxyacetic acid (2,4–D) had an increased storage life, compared with fruit from nonsprayed trees. This resulted from a decrease in black-button (blackened-calyx) formation and attendant Alternaria rot, as well as from a reduction in external decay. Washington Navel oranges from trees sprayed with 2,4–D likewise had fewer black buttons than fruit from nonsprayed trees. In one test with lemons, 2,4,5–trichlorophenoxyacetic acid (2,4,5–T) spray was considered more effective than 2,4–D in inducing these responses.

Lemons dipped in 2,4–D solutions or exposed to 2,4–D vapor, or coated with 2,4–D in wax after harvest, likewise had an increased storage life, compared with nontreated fruit, owing to a reduction in black buttons, internal Alternaria decay, and external decay.

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The Use of Bee-Collected Pollen in Artificial Pollination of Deciduous Fruits

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Although bee-collected pollen can be readily obtained in almost unlimited quantities by the use of pollen traps (4, 6), no evidence has been presented which indicates that it can be used successfully to replace hand-collected pollen in commercial artificial pollination. A person collecting pollen by hand gathers about 20 volume ounces of apple blossom anthers per day; 6 to 8 ounces of such green anthers are required to produce 1 ounce of cured pollen (1). On the other hand, a pollen trap will yield as much as 2½ pounds of pollen per day per colony of bees under favorable conditions.

The pollen pellets of a honey bee generally contain pollen grains from only one species of plant, and the pellets of the common fruit species are readily distinguished by their color. Although all bees of a colony do not visit the same species, it is possible to get nearly a pure sample by careful selection of the time and place of trapping. The pureness of some collections of pollen is shown in Table I.

TABLE I—Percentage of Desired Species of Pollen Obtained from Pollen Traps in California Orchards (1947)

Polled Desired	Collection		Per Cent Desired Pollen Obtained
	Date	Place	
Almond	Feb 24	Winters	95
Sweet cherry	Mar 19	Cortland	75
Sweet cherry	Mar 23	Cortland	40
Pear	Mar 19	Cortland	10
Pear	Mar 26	Cortland	65
Pear	Mar 26	Placerville	85
European plum	Mar 20	Woodland	99
Apple	Apr 19	Santa Rosa	73

Kremer (3) suggested that bee-collected pollen from early blooming apple varieties could be mixed with lycopodium spores and stored under dry conditions at 34 to 36 degrees F. Later this mixture can be used in pollen-distributing traps inserted at the entrance of bee colonies for the cross-pollination of varieties which blossom late in the spring. He warned, however, that the bee-collected pollen loses its viability quite rapidly, even under the best of conditions. Singh and Boynton (5) reported a continuous decline in germination as well as in ability to effect fruit set of practically all samples of bee-collected apple pollen. They report that most of the decline in viability appeared to take place during the first 2 hours of storage.

Studies in California Prior to 1948[1]

Studies to determine the value of bee-collected pollen in artificial pollination have been conducted in the deciduous fruit areas of Cali-

[1]Unpublished data by C. O. Hesse, University of California, Davis, Calif., J. R. King, formerly of the University of California; and George H. Vansell.

fornia since 1944. Both emasculated and perfect flowers were used, and in most tests hand-collected pollen was used as a control. Various concentrations of pollen-water mixtures were sprayed on almond, pear, and plum blossoms with hand and power sprayers. In one orchard near Hamilton City, 45 mature Winter Nelis pear trees were pollinated in this manner. The pellets were also mixed with walnut shell powder and dusted on the blossoms with hand dusters. In other trials the blossoms were pollinated by gently crushing the pellets on the hands and touching the stigmas with the fingers. In 1945 four Bartlett pear trees which had been completely enclosed with cheesecloth cages prior to the blossoming period were sprayed with pellet pollen suspended in 5 and 10 per cent cane-sugar sirup as well as in water. In all experiments the bee-collected pollen failed to increase fruit set significantly. However, a study of the weather conditions during and following the days when the pollens were applied reveals that in nearly every instance low temperatures and rains could have been partially responsible for the low fruit sets.

Samples of bee-collected pollen from almond, sweet cherry, French prune, and Bartlett pear blossoms were collected in different counties during the period from February 20 through March 26, 1947. The samples were stored at 32 degrees F in open-topped petri dishes in dessicators with the relative humidity adjusted to 25 per cent with sulphuric acid. Upon collection the germination ranged from 20 to 34 per cent on a medium consisting of 2 per cent agar and 10 per cent cane sugar. By the first of June, germination ranged from 5 per cent to 0, and by July 1 it was practically nil for all samples. However, a few pollen grains from each sample, except those for sweet cherry, germinated on July 1 when they were tested on a medium of 2 per cent agar and 20 per cent cane sugar.

Samples of the sweet cherry pollen were also stored at 36, 32, and 15 degrees F with relative humidity combinations of 0, 15, 25, and 50 per cent. By June 4 the only germination was 3 per cent from the samples stored at 15 degrees F. The different humidities had no apparent effect on viability. By July 1 less than 1 per cent of the pollen stored at 15 degrees F germinated on the medium containing 10 per cent sugar, but when the sugar content was doubled, germination again averaged 3 per cent.

Materials and Methods

Since higher germination of the bee-collected pollen occurred following storage when the sugar content of the medium was increased, laboratory tests were made during the spring of 1948 with various concentrations of cane-sugar sirup as a diluent for the pellets. The pollen-sirup mixtures were tested for germination on media consisting of 2 per cent agar and 10, 15, and 20 per cent cane sugar. These tests revealed that fruit pollen from freshly gathered pellets, when suspended in 15 or 20 per cent sirup and then tested on an agar medium containing 20 per cent cane sugar, germinated as well or better than hand-collected pollen. Samples of almond, cherry, and pear pellet pollen gave a range of from 46 to 80 per cent germination by this method. Germi-

nation was reduced to 1 per cent or less in from 5 to 10 days at room temperature. When stored in paper bags at 32 degrees F, samples of bee-collected almond pollen gave germination percentages of 26 to 64 per cent 22 days after they were collected. Pellet pollen from cherries and pears ranged from 37 to 57 per cent germination after 7 days at 32 degrees F.

Next it was necessary to learn whether or not pollen from the pellets could effect a satisfactory fruit set immediately after it was collected, before making further attempts to increase its viable storage life. Therefore, all of the bee-collected pollen used in the 1948 studies, except that of the Early Wilder pear, was obtained by capturing the bees with a hand net, while they were gathering pollen from the desired varieties. Within a few minutes after the pellets were gathered they were dissolved in a small vial of either distilled water or 15, 20, or 30 per cent cane sugar sirup. The resulting mixture of pollen and liquid was immediately applied to the stigmas with a glass stirring rod. The hand-collected pollen was also applied with a stirring rod.

All blossoms which were artificially pollinated were emasculated in the popcorn stage, and only two or three blossoms per cluster were left. Bagging was not practiced, but additional branches on the same trees were emasculated but not pollinated while others were either pollinated with hand-collected pollen or used to determine the fruit set resulting from open pollination. The tests were made on bearing trees ranging from 25 to 40 years old. The number of fruits which set were counted before the June drop, but the mean fruit sets presented were calculated from the number of fruits which matured. The pears and apples were harvested, weighed, and examined for seed content. Fruits containing one or more filled seeds were classified as seeded.

RESULTS AND DISCUSSION

Sweet Cherries:—Pellets, collected from bees working different cherry varieties, were applied to blossoms of Bing, Bush Tartarian, Napoleon, and Pontiac trees in the cherry variety orchard at Davis on March 30, 31, and April 1. In addition to applying water and sirup mixtures of the pellets, pellets were gently rubbed on the stigmas of several hundred blossoms by hand. Of a total of 2,918 blossoms pollinated with the bee-pellets on the above varieties, a mean fruit set of 0.4 per cent was effected. Twelve varieties of hand-collected pollen applied to 4,914 blossoms on these same trees effected a mean set of 3.2 per cent, while 1,715 open-pollinated blossoms had a mean set of 38.0 per cent. Not a single fruit set on 1,796 blossoms which were emasculated only.

No rain fell during the period in which the pollens were applied, and the average maximum and minimum temperatures for the 3 days were 68 and 43 degrees F respectively. Rain occurred April 2, and the average maximum temperature for April 2, 3, and 4 dropped to 58 degrees F and the average minimum temperature to 41 degrees.

On April 14 two branches with a total of 352 blossoms on a late-blooming variety, Lambert, were pollinated with bee-pellets taken from bees working Ord and Deacon cherry trees and dissolved in 20 per cent

cane sugar sirup. A mean set of 9.8 per cent resulted. Hand-collected Deacon pollen applied to 945 blossoms on this tree gave a 10.9 per cent set, and the set resulting from open pollination was 18 per cent. The maximum and minimum temperatures for April 14 were 57 and 49 degrees F respectively. Light showers occurred on April 15, 16, and 17, and the temperature averaged approximately 10 degrees higher than that for the 3 days following the earlier cherry pollinations.

Hardy Pears:—On April 12 and 13 bee-collected Early Wilder pollen dissolved in 20 per cent sugar sirup and hand-collected Winter Nelis and Bartlett pollen were applied to the blossoms of Hardy pear trees growing in a solid block at Danville. The bee-pellets were trapped April 10 and 11 from colonies of bees in a solid block of Early Wilder trees near Winters and stored at 32 degrees F. Samples of the pollen from the pellets showed germinations of 30 to 40 per cent on the days it was applied. Hand-collected pollen from the same Early Wilder orchard in which the pellets were trapped was used to pollinate a branch on each of two of the Hardy trees with a total of 481 blossoms. A mean fruit set of 22 per cent resulted, and 98 per cent of the fruits contained filled seeds. The average maximum temperature for April 12 and 13 was 59 degrees F, and the average minimum temperature was 43 degrees. A light shower occurred during the afternoon of April 13. Light showers also occurred on April 15 and 16. No freezing temperatures occurred after the pollinations. The mean fruit set, proportion of seeded fruits, and weight per fruit resulting from the pollinations are shown in Table II.

The hand-collected Winter Nelis and Bartlett pollen effected greater fruit sets and higher proportions of fruits containing filled seeds than did bee-collected pollen, emasculation only, and open pollination. The mean weights of the fruits resulting from open pollination, as well as the two varieties of hand-collected pollen, were significantly greater than those obtained from blossoms pollinated with bee-pellets or emasculated only.

The mean per cent set and the mean weight of the fruits which developed from the blossoms pollinated with the bee pollen were not significantly greater than that resulting from emasculation only. However, not one filled seed developed from the unpollinated blossoms, and the filled seeds in 13.4 per cent of the fruits which developed from the blossoms pollinated with the pellet pollen show that it is capable of effecting normal pears. The mean weight of these seeded fruits was 77.0 grams. This was not significantly different from the mean weights of the seeded fruits resulting from the hand-collected pollen and open pollination.

Bartlett Pears:—On April 7 a total of 2,914 blossoms on branches of six Bartlett pear trees at Davis were pollinated with bee-collected Early Wilder pollen which had been trapped on April 6 in the Early Wilder orchard mentioned above. The pellets were dissolved in water or 20 per cent sugar sirup, and applied with a small hand sprayer as well as with glass stirring rods. The maximum and minimum temperatures for April 7 were 58 and 33 degrees F respectively. Light showers occurred April 8, 9, and 10, and cool weather continued until April 13.

TABLE II—EFFECT OF EMASCULATION AND CROSS-POLLINATION WITH BEE-COLLECTED AND HAND-COLLECTED POLLEN ON THE FRUIT SET, SEED CONTENT, AND WEIGHT OF HARDY PEARS (DANVILLE, CALIFORNIA, 1948) (MEANS ARE FOR THIRTEEN TREES)

Treatment of Blossoms	Number of Blossoms Used	Mean Per Cent Fruit Set	Mean Per Cent Seeded Fruits	Mean Weight Per Fruit (Grams)	Mean Weight Per Seeded Fruits (Grams)
Emasculated and pollinated with:					
Bee-pellets† in 20 per cent cane sugar sirup	2,990	2.5	13.4	54.4	77.0
Winter Nelis pollen (hand-collected).	1,786	12.7	73.5	72.2	77.6
Bartlett pollen (hand-collected)	1,255	13.8	84.0	70.3	74.1
Emasculated only.	1,558	1.9	0.0	55.0	—
Open pollinated	4,654	5.9	41 9	75.5	85.4
Difference required for significance					
5.0 per cent level		3.8	18 6	13.6	
1.0 per cent level		5 1	24.8	18.2	
F value for treatments		16.7**	29.9**	4.4**	

†Trapped from bees working Early Wilder pear blossoms.
**Significant beyond the 1 per cent level.

Only two fruits resulted from this study. They developed from blossoms which had been pollinated by applying the sirup-pollen mixture with glass rods. One of these fruits contained one filled seed and the other was parthenocarpic. One parthenocarpic fruit developed from the blossoms which were emasculated but not pollinated. Although the trees were interplanted with Winter Nelis, the fruit set resulting from open pollination was very light, estimated to be only 2 per cent.

On April 23 and 24 blossoms of Bartlett pear trees growing in a solid block near Camino were pollinated with bee-pellets in different concentrations of sirup and with hand-collected pollen. The pellets were taken from bees working Winter Nelis and Bosc blossoms. The number of blossoms used for each treatment was limited, because bee activity was light and only a small quantity of pellets was obtained. The average maximum and minimum temperatures for the 2 days were 59 and 35 degrees F respectively. The cold weather continued, and on April 29 the temperature dropped to 27 degrees F.

The data obtained are shown in Table III. None of the variously pollinated blossoms gave significantly higher fruit sets than the parthenocarpic set resulting from emasculation only. The unfavorable effect of the low temperatures during the blossoming period on germination and fertilization is shown by the low percentages of seeded fruits which developed from either open-pollinated or hand-pollinated blossoms.[2] High parthenocarpic sets of Bartlett were also reported by Dwyer and Bowman (2), who found that the years of greatest parthenocarpic fruit set were characterized by moist conditions and low temperatures during, and for a short time after, the blossoming period. Therefore, the effectiveness of the hand-collected as well as the bee-collected pollen must be determined from the number of seeded fruits rather than from the total number of fruit set. The few seeded fruits

[2]The hand-collected Winter Nelis and Early Wilder pollens were from the same collection which was used on the Hardy trees at Danville, where they effected a much higher proportion of seeded fruits.

TABLE III—EFFECT OF EMASCULATION AND CROSS-POLLINATION WITH BEE-COLLECTED AND HAND-COLLECTED POLLEN ON THE FRUIT SET, SEED CONTENT, AND WEIGHT OF BARTLETT PEARS (CAMINO, CALIFORNIA, 1948) (MEANS ARE FOR FROM TWO TO TWELVE TREES)

Treatment of Blossoms	Number Blossoms Used	Mean Per Cent Fruit Set	Mean Per Cent Seeded Fruits	Mean Weight Per Fruit (Grams)
Emasculated and pollinated with:				
Bee-pellets† in 15 per cent cane sugar sirup	228	8.3	12.5	76.6
Bee-pellets† in 20 per cent cane sugar sirup	902	11.0	0.8	76.1
Bee-pellets† in 30 per cent cane sugar sirup.	535	9.6	6.7	76.6
Winter Nelis pollen (hand-collected).	203	16.0	5.0	67.9
Early Wilder pollen (hand-collected) in 15 per cent cane sugar sirup	293	8.6	0.0	99.4
Early Wilder pollen (hand-collected)	497	12.4	1.0	75.6
Emasculated only	1,500	9.3	0.0	80.3
Open pollinated	5,991	4.0	10.9	97.2
F value for treatments		3.4**	2.2*	2.1

†Collected from bees working Bosc and Winter Nelis pear blossoms.
*Significant beyond the 5 per cent level.
**Significant beyond the 1 per cent level.

which developed following pollination with bee-collected pollen again indicate that it is possible to get normal fruits with it.

There were no significant differences in the weights of the fruits which developed following the treatments or between the treatments and open pollination.

Apples:—On May 5 bee-collected pollen was used to pollinate interplanted Delicious and Golden Delicious apple trees near Placerville. The temperature ranged in the seventies, and the day was ideal for bee activity. No freezing temperatures followed the pollinations, and no rain occurred for several days thereafter. Pellets from bees working Golden Delicious blossoms were dissolved in sirup and applied to the Delicious blossoms. Then pellets from bees working Delicious blossoms were used to pollinate the Golden Delicious. Hand-collected Delicious pollen was also used to pollinate a branch on each of the Golden Delicious trees. The resulting data are shown in Table IV.

The pollen from the pellets gave a fair set on the Delicious blossoms, and the mean set on the Golden Delicious was as satisfactory as that of hand-collected Delicious pollen or open pollination. No fruits developed on the branches which were emasculated only. The effectiveness of the bee-collected pollen is further shown by the fact that the fruits which developed following its application contained approximately the same number of seeds as those resulting from open pollination and hand-collected pollen. The fruits which resulted from pollination with bee-pellets were as large as those resulting from hand-collected pollen.

SUMMARY AND CONCLUSIONS

With pears the fruit sets following the applications of bee-collected pollen in water and in sirup mixtures were either nil or insignificant. On the other hand, the results following the application of pollen-sirup mixtures to Lambert cherry and Delicious and Golden Delicious apple blossoms indicate that under favorable weather conditions the pollen

TABLE IV—EFFECT OF EMASCULATION AND CROSS-POLLINATION WITH BEE-COLLECTED AND HAND-COLLECTED POLLEN ON THE FRUIT SET, SEED CONTENT, AND WEIGHT OF DELICIOUS AND GOLDEN DELICIOUS APPLES (PLACERVILLE, CALIFORNIA, 1948) (MEANS ARE FOR TWO TREES)

Treatment of Blossoms	Number of Blossoms Used	Mean Per Cent Fruit Set	Mean Seeds Per Fruit	Mean Weight Per Fruit§ (Grams)
Delicious				
Emasculated and pollinated with:				
Bee-pellets* in 15 per cent cane sugar sirup	229	4.9	7.5	66 9
Bee-pellets* in 20 per cent cane sugar sirup	298	7.0	6 7	77.8
Emasculated only	291	0.0	—	—
Open pollinated	—	10.0‡	7.7	100.0
Golden Delicious				
Emasculated and pollinated with:				
Bee-pellets† in 15 per cent cane sugar sirup	215	17.9	8.4	77.7
Delicious pollen (hand-collected)	278	15.8	8.5	67.1
Emasculated only	257	0.0	—	—
Open pollinated	—	15.0‡	9.1	99.4

*Collected from bees working Golden Delicious apple blossoms.
†Collected from bees working Delicious apple blossoms.
‡Estimated.
§Fruit picked 3 weeks before commercial harvest.

from freshly gathered bee-pellets is capable of effecting satisfactory fruit sets. Thus, further studies must be made before bee-collected pollen can be recommended for commercial artificial pollination.

Fruit pollen from freshly gathered pollen pellets of honey bees shows germination percentages which compare favorably with hand-collected pollen when the pellets are first dissolved in 15 or 20 per cent cane-sugar sirup and the resulting mixture tested on an agar-sugar medium containing 20 per cent cane sugar.

The tendency toward parthenocarpy of Hardy and Bartlett pear varieties makes it necessary to use the number of seeded fruits rather than the total number of fruits set in determining the effectiveness of a pollinizer.

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Handling and Application of Pollen to Fruit Trees[1]

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Artificial pollination of tree fruits on a commercial basis was started in the state of Washington approximately 20 years ago. Since that time, many orchards with inadequate pollination by natural means have been pollinated artificially; these, for the most part, produced greatly increased crops as a result of the practice. In general, the increase was greatest where pollination by natural means was not satisfactory. The need for artificial pollination is most generally with apples, although some attention has been given to pears, sweet cherries and plums in recent years.

The blossom period, during which pollination may be done, is short. The pollen must be collected, dried and applied within a few days. Artificial pollination has been considered costly, since hand labor has been necessary for all operations. It is for the purpose of lowering these costs that this study was initiated in 1946.

The greatest improvement in the pollination program appears to be with the application of the pollen. This investigation deals specifically with commercially introduced airplane and bomb methods of application. Special attention was directed to (a) fruit set resulting from applying pollen with the airplane and bomb; (b) the germination of pollen applied with the airplane and bomb; and (c) the handling of artificially collected pollen.

In determining the need for artificial pollination, it is very important that each grower carefully evaluate his own particular situation with regard to the pollinator trees or grafts that he is growing and the bee or other insect population in the orchard. Many growers consider artificial pollination as insurance and supplement it with bees and bouquets, however, many other orchardists find the operation an added expense. Fruit set on branches of four Delicious apple trees in an orchard where adequate pollinator trees and bees were present is shown in Table I.

Under conditions shown in Table I, artificial pollination would be an added expense. Overley and Bullock (2) have reported that where 3 to 5 per cent of a heavy bloom on apple trees sets fruit, a good commercial crop is assured.

Fruit Set Resulting From Applying Pollen With the Airplane and Bombs in Addition to Normal Pollination

Airplane Application of Pollen:—Many growers have used this method of applying pollen to apple and sweet cherry orchards in the past three years. Pollen designed for airplane application is diluted with a less-expensive substance or diluent and the mixture is applied as a dust.

In comparing the fruit set obtained by airplane application of pollen

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TABLE I—FRUIT SET ON FOUR DELICIOUS APPLE TREES IN AN ORCHARD WHERE ADEQUATE POLLINATOR TREES AND BEE POPULATIONS WERE PRESENT (1947)

Position on Tree	No. Flowers	Per Cent Set
SW 8′	621	5.79
SE 6′	483	10 14
E 6′	378	5.02
W 8′	772	5 18
N 8′	266	4.88
NE 8′	1,155	6 32
N 6′	345	8 69
SW 6′	424	8.96
SE 8′	772	7.77
SE 6′	644	5.59
N 8′	465	8 81
N 6′	522	6.13
N 8′	729	5.76
E 6′	424	7 31
E 10′	1,168	8.30
E 6′	754	9.28
S 8′	925	9 29
S 6′	746	10 18
W 6′	429	5.59
	12,022	7.42

with normal pollination, the paired branch method was used. Two branches, as nearly alike as could be found in the same position, were selected at various locations on the trees. One of these branches was covered with a finely woven muslin sack, while the airplane was flying over the orchard. The muslin sack was removed after the plane left the area. Fruit set counts were made following the June drop. The results of this study are shown for Delicious apples in Table II. Significance was determined by Student's Method for comparing paired values (3). Two years data are shown in Table II from paired branches on 30 Delicious apple trees from eight orchards.

No significant increase in fruit set was obtained in Delicious apples by this method of artificial pollination. A slight increase in set has been reported by Overley and Bullock (2) for Winesap apples, but the data are not set up for statistical treatment. Airplane pollination cannot be recommended at this time as providing insurance for obtaining a set of fruit.

Bomb Application of Pollen:—The pollen bomb, as described by Overley and Bullock (2), is composed of a heavy cardboard cylinder with a fused impelling charge of explosive powder in the base. The cylinder is filled with a carrier for the pollen. The pollen was placed on top of the carrier just prior to placing the bomb under the tree to explode. The results of bomb pollination on Delicious apples is shown in Table III, and for Bing cherries, in Table IV.

In comparing pollination by bomb with normal pollination, the paired branch method was used as described above for airplane pollination and the results compared by using Student's Method for comparing paired values (3).

No significant increase in fruit set was obtained by this method of applying pollen to Delicious apples or to Bing cherries. Similar data presented by Overley and Bullock (2) and Bullock and Snyder (1) have shown no significant increase in fruit set by this method of apply-

TABLE II—EFFECT OF AIRPLANE POLLINATION IN ADDITION TO NORMAL POLLINATION ON PAIRED BRANCHES OF DELICIOUS APPLE TREES (DILUENT, LYCOPODIUM)

Position on Tree	Pollination by Plane in Addition to Normal Pollination		Normal Pollination Only		Increase Set by Plane
	No. of Flowers	Per Cent Set	No. of Flowers	Per Cent Set	
N 12′	110	12.72	83	1.20	11.52
N 7′	88	11.36	66	0.0	11.36
S top	99	8.08	121	4.95	3.13
SW 8′	88	13.63	83	15.66	-2.03
SE 7′	88	10.22	88	2.27	7.95
N 12′	94	6.38	110	9.09	-2.71
NW 8′	99	4.04	72	2.77	1.27
S top	127	2.36	105	5.71	-3.35
SW 7′	121	3.30	88	3.40	-0.10
SE 5′	132	4 54	105	11.42	-6.88
NW 7′	83	10.84	116	4.31	6.53
W 10′	121	6 61	88	14.77	-8.16
SE top	143	11.88	116	1.72	10.16
E 3′	105	12.38	121	2.47	9.91
SW 7′	116	6.03	116	4.31	1.72
S 6′	110	7.27	83	9.63	- 2.36
NW 6′	143	9.09	132	8.33	0.76
SE 7′	149	6 71	160	8.75	-2.04
M top	105	8.57	88	1.13	7.44
NE 8′	94	7.44	138	7.97	- 0.53
S 8′	110	8 18	110	4.54	3.64
E 8′	127	4 72	116	7.75	-3.03
NW 8′	99	14.14	77	9.09	5.05
NE 15′	110	0.0	99	1.01	1.01
M top	127	9.44	66	12.12	2 68
S 7′	105	11.42	176	8.52	2.90
SW 9′	105	14.28	143	8.19	6.09
N 9′	110	9 09	88	4.54	4.55
M top	72	2.77	105	5.71	-2.94
M top	154	7.79	110	3.63	4.16
NW 6′	143	1.39	193	2.59	-1.20
N 14′	55	1.81	50	6.00	-4.19
M top	61	1.63	88	7.95	-6.32
E 8′	116	2.58	83	4.81	- 2.23
N 9′	105	7.61	83	3.61	4 00
SW 8′	88	10.22	99	5.05	5.17
N 7′	127	7.87	72	0.00	7.87
SW 8′	66	9.09	66	4.54	4.55
SE 9′	77	5.19	94	3 19	2.00
M top	83	3.61	116	2.58	1.03
S 12′	143	3 49	66	3.54	-1.05
E 6′	110	7.27	105	3.80	3.47
M top	72	8.33	83	7.22	1.11
SW 12′	160	5.00	121	4.95	0.05
E 14′	72	1.42	121	3.30	-1.88
SE 16′	121	8.26	105	3.80	4.46
NW 7′	149	3.35	94	1.06	2.29
SE 5′	110	7.72	127	7 08	0.19
S 7′	273	2.54	110	3 63	- 1.09
SW 9′	434	1.61	176	3.40	-1.79
N 9′	159	0.99	121	1.65	- 0.66
M top	99	2.02	82	3.65	-1.63
N 14′	220	1.36	192	3.12	-1.76
E 8′	302	1.32	55	3.63	-2.31
SW 8′	242	0.41	154	2.59	-2.18
SE 9′	121	6.61	165	4.84	1.77
S 12′	242	3.30	176	1.13	2.17
E 6′	115	5.21	132	3.03	2.18
NW 6′	33	0.00	660	3.03	-3.03
SE 7′	203	1.47	221	4.52	- 3.05
N 6′	104	5.76	137	5.11	0.65
NE 7′	127	5.51	218	3.21	2.30
E top	334	8.38	127	7.08	1.30
NW top	184	3.80	110	2.72	1.08
M top	110	7.27	81	8.64	- 1.37
W 6′	92	5.43	92	7.60	-2.17
NE 6′	98	4 08	92	4.34	-0.26
SE 6′	161	5.59	122	4.09	1.50
S top	138	2.89	133	3 00	- 0.01
N top	122	4.09	122	4.09	0.00
N top	138	5.07	116	1.72	3.35
S 6′	184	4.89	122	1.63	3.26

TABLE II—*Concluded*

Position on Tree	Pollination by Plane in Addition to Normal Pollination		Normal Pollination Only		Increase Set by Plane
	No. of Flowers	Per Cent Set	No. of Flowers	Per Cent Set	
W 6′	122	4.91	178	3.37	1.54
NW 8′	127	7.08	172	3.93	3.15
SE 6′	236	2.96	92	3.26	0.30
SE top	138	3.62	116	5.17	· 1.55
W top	116	5.17	104	5.76	-0.59
N 8′	144	1.38	219	0.45	0.93
E 6′	144	0 69	144	4.16	-3.47
SE 6′	196	2.55	184	1.08	1.47
S 19′	122	11.47	122	12.29	-0.82
SE 14′	110	6.36	127	7.87	-1.51
NW 18′	248	13.70	161	12.42	1 28
W 6′	104	5.76	167	6.58	-0.82
NE 5′	122	4.09	133	7.51	-3.42
S 6′	150	10.66	87	6.89	3.77
E 20′	184	11.41	75	13.33	-1.92
SE 18′	127	11.02	116	19.82	--8.80
NW 17′	144	4.86	116	12 93	-8.07
SW 5′	219	7.76	127	7.08	0.68
NW 7′	127	7.08	161	7.45	-0.37
NE 6′	116	10.34	98	5.10	5.24
SE 6′	207	9.66	87	9.19	0.47
E 10′	161	11.80	110	9.09	2.71
N 15′	288	7.63	110	14.54	6.91
S 16′	133	10.52	144	7 63	2.89
S 14′	184	5.97	122	6 55	-0.58
NW 5′	190	5.78	184	9.23	-3.45
NE 10′	173	7.51	161	3.72	3 79
SW 6′	150	8 66	150	7.33	1 33
NW 8′	322	5.90	122	7.37	-1 47
NE 6′	127	7.08	138	5.07	2 01
S 6′	127	5.51	155	9.03	-3.52
M top	184	5.43	93	13 97	- 8.54
M top	150	3.33	144	4.86	- 1.53
E top	116	6.03	178	4 49	1 54
E 5′	184	7.06	133	0.75	6.31
N 6′	207	7.72	144	2.77	4.95
M top	178	4.49	196	4.59	-0.10
E top	122	7.37	98	10.20	-2.83
W 6′	110	0.00	150	8 66	- 8.66
N 5′	190	2.10	138	5 79	3.69
SE 8′	265	4.15	192	2.08	2.07
M 16′	173	6.93	110	4.54	2.39
M 18′	225	7.11	104	7.69	-0 58
W 12′	196	9.18	161	4 96	4.22
W 6′	104	7.69	155	9.03	-1.34
NW 8′	150	10.00	116	6.03	3.97
NE 6′	110	2.72	69	5.79	-3.07
SE 12′	207	4.83	207	7.72	-2.89
SE 6′	230	10.43	110	9.09	1.34
	17,588	6.25	15,337	5.53	
			Mean Difference—		0.48
			Difference Required at		.05–0.717

ing pollen to Winesap apples or to Bing, Lambert, or Royal Anne cherries.

Germination and Dispersion of Pollen as Applied by Airplane and Bomb

Since no increase in fruit set was obtained by either of the above artificial methods in these studies, the question arises as to the viability of the pollen after being applied by these methods and also, of the dispersion of the pollen through the tree.

To determine the viability of the pollen following application, depression slides containing a 10 per cent sugar solution in the depressions were placed in open petri dishes on a piece of moist filter paper.

TABLE III—EFFECT OF BOMB POLLINATION IN ADDITION TO NORMAL POLLINATION ON PAIRED BRANCHES OF FOUR DELICIOUS APPLE TREES

Position on Tree	Pollination by Bomb in Addition to Normal Pollination		Normal Pollination Only		Increase Set by Bomb
	No. of Flowers	Per Cent Set	No. of Flowers	Per Cent Set	
SE 6′	104	5.76	104	0.96	4.80
S 8′	127	2.36	116	0.86	1.50
S 17′	161	3.72	104	5.76	-2.04
E 16′	87	4.59	82	2.43	2.16
SE 8′	161	3.72	93	2.15	1.57
S 5′	155	1.29	76	6.57	-5.28
SE 5′	87	2.29	110	5.45	-3.16
S 6′	87	5.74	87	3.44	2.30
SW 6′	161	1 24	127	6.29	-5.05
S 12′	116	4.31	116	4.31	0.00
N 14′	150	9.00	127	3.93	4.07
S 7′	155	3.87	133	8.24	-4.40
E 6′	116	4.31	122	4.09	0.22
W 8′	150	6.66	138	4.34	2.32
N 5′	122	3.27	87	1.14	2.13
SW 8′	201	3.98	155	4.51	-0.53
	2,140	4.01	1,777	4.16	
			Mean Difference—		0.04
			Difference Required at .05—		1.68

TABLE IV—EFFECT OF BOMB POLLINATION IN ADDITION TO NORMAL POLLINATION ON PAIRED BRANCHES OF FOUR BING CHERRY TREES

Position on Tree	Pollination by Bomb in Addition to Normal Pollination		Normal Pollination Only		Increase Set by Bomb
	No. of Flowers	Per Cent Set	No. of Flowers	Per Cent Set	
E 6′	176	2 27	386	6.21	-3.94
S 6′	173	2.89	268	1.86	1.03
N 6′	476	4.62	648	6.01	-1.39
W 5′	246	13.00	248	7 25	5.75
N 8′	356	6.17	313	10.54	-4.37
S 6′	604	19.37	560	7.14	12.23
E 12′	744	7.39	648	9.10	-1.71
E 18′	325	8 00	136	9.55	-1 55
E 20′	508	35.03	620	29.51	5.52
NW 17′	290	7.58	230	10.43	-2 85
S 17′	436	23.62	536	28.91	-5.29
NE 6′	296	12.50	224	12.50	0.0
W 18′	301	7.97	383	4.17	3.80
W 10′	720	10.97	760	13.81	-2 84
N 18′	704	21.73	656	18.44	3.29
M top	356	11.79	268	25.00	-13.21
SW 19′	392	7.14	360	7.50	-0.36
N 20′	312	14.10	328	25.30	-11.20
NE 12′	680	12 79	656	13.71	-0.92
NW 10′	304	18.09	268	25.00	-6.91
E 7′	420	10.47	428	14.95	-4.48
W 14′	408	10.78	408	10.29	0.49
W 12′	320	9.37	288	14.58	-5.21
SW 14′	648	16.20	392	10.45	5.55
SE 12′	600	18.00	292	22.94	-4.94
	10,795	13.58	10,304	14.10	
			Mean difference—		-1.34
			Difference Required at .05—		2.28

During the application, the petri dishes were placed in the tree and under the tree. Immediately after the application, the dishes were closed and taken into the laboratory for germination. The results are shown in Table V.

TABLE V—VIABILITY OF APPLE POLLEN FOLLOWING APPLICATION BY AIRPLANE AND BOMB

Position in Tree	Airplane Pollination		Bomb Pollination	
	Grains Counted	Per Cent Germination	Grains Counted	Per Cent Germination
S 10′	110	46.4	100	0
W 10′	75	52.0	58	0
N 12′	86	40 6	51	0
E 14′	74	40 5	40	7.5
Top middle	92	45 6	35	0
Top middle	90	41.1	31	0
S 6′	120	51.6	82	6.1
W ground	70	54.2	135	1 5
N ground	54	40.7	110	0
E 8′	68	54.4	60	1.6
Checks	200	61.0	200	78.5
Checks	200	65 0	200	63.0

Dispersion of the pollen was determined by hanging glass slides, covered with an organic oil and suspended from various points throughout the tree. After application of the pollen, the slides were taken into the laboratory and the pollen grains observed.

Germination of pollen following application by airplane was excellent while following application by bomb was very low. The cause of this low viability has not been determined. In all cases, the pollen was being spread through the tree in fair to good amounts as evidenced by pollen grains adhering to the slides.

TABLE VI—DISPERSION OF POLLEN FOLLOWING APPLICATION BY AIRPLANE AND BOMB

No	Position	Dispersion	
		Airplane	Bomb
1	Top middle	Good	Fair
2	¾ S	Good	Fair to good
3	¾ N	Very good	Fair
4	¾ E	Good	Good
5	½ S	Fair	Good
6	¼ W	Fair	Good
7	¼ N	Fair to good	Good
8	¼ E	Fair	Good

HANDLING OF ARTIFICIALLY COLLECTED POLLEN

Pollen is an extremely perishable product, and all handling of it must be done with this fact in mind. Pollen gathered from the orchard is immediately placed in drying trays and cured. Following the curing process, it should be kept in 34 degrees F storage at all times that it is not being used. If the pollen is to be stored for more than a few days, it should be kept at 34 degrees F and at 25 per cent relative humidity to make certain that it remains dry.

In applying pollen by any of the artificial methods, it is advisable to mix with a diluent as this enables a more economic distribution of the pollen since it is a very expensive product. During the past season, some 37 different materials were used as pollen diluents in an effort

to find an inexpensive material. These materials were selected at random for their physical properties rather than their chemical properties.

Materials under study as pollen diluents this season include the following:

1. Lycopodium
2. Powdered milk (non-fat)
3. Casein
4. Sodium caseinate
5. Egg albumen
6. Asparagin
7. Sodium asparaginate
8. Papain
9. Pepsin
10. Urea
11. Peptone powder
12. Unirradiated dry yeast
13. Lactose
14. Dextrose
15. Levulose
16. Maltose
17. Sucrose
18. Mannite
19. Bacto dextrose
20. Bacto agar
21. Agar agar
22. Malt extract agar
23. Malt extract
24. Diastase
25. Corn starch
26. Walnut hull flour
27. Whole wheat flour
28. Wheat flour
29. Soy flour
30. Wheat dextrines
31. Cake flour
32. Zinc stearate
33. Charcoal
34. Talc
35. Calcium carbonate
36. Dicolete
37. Filtrol (X415)

Each material was ground to pass a 60-mesh screen or smaller. Some materials are somewhat finer than this naturally. Pollen was mixed with the materials at the rate of 25 per cent pollen to 75 per cent of the diluent and placed in small vials from which samples of pollen-diluent mixture were taken at intervals for germination counts. The same varieties of pollen without diluent were germinated at the same time as checks. The results are shown in Table VII for some of the more promising materials.

The pollen was germinated in a 10 per cent sucrose solution placed in depression slides. The slides were incubated at 70 degrees F for 12 to 18 hours in petri dishes with a moist filter paper used as a humidifier. Tests were made in duplicate, and 200 pollen grains were counted in each test at random over the slide depression.

In this investigation, three materials were outstanding as pollen diluents in regard to the pollen maintaining its viability in storage. Powdered milk (non-fat), egg albumen and lycopodium all appear to have equal merit, with the first two being more readily available and less expensive than lycopodium at the present time. Only very limited

TABLE VII—Germination of Apple Pollen Mixed With a Diluent and Stored at 34 Degrees F and 25 Per Cent Relative Humidity

Diluent	Per Cent Germination				
	Apr 16	Apr 28	Nov 15	Nov 24	Nov 25
Lycopodium	80	80	80	75	75
Powdered milk	70	70	65	75	80
Egg albumen	75	80	70	75	80
Lactose	70	65	30	70	70
Sodium caseinate	35	30	30	35	20
Maltose	50	45	50	60	50
Bacto dextrose	50	45	35	50	30
Bacto agar	60	70	30	30	35
Diastase	40	45	30	30	25
No diluent	87	85	40	35	40

field trials have been made with these materials. From these limited trials, it can be said that they show definite promise as practical pollen diluents, however, more extensive field applications must be made before they can be shown to have a place in this capacity.

Several of the sugars such as lactose, maltose, bacto dextrose and materials such as bacto agar, sodium caseinate and diastase showed promise as diluents, but do not appear to be practical at the present time.

Some materials such as casein and agar agar did not show the promise that was expected, possibly because of improper particle size or improper handling. With the promise shown by such readily available materials as powdered milk and egg albumen, casein and agar agar probably would not prove practical as pollen diluents. If powdered milk and egg albumen perform as well in extensive field trials as they have in limited field trials, in pollen storage and germination studies, they will be the most practical pollen diluents of the materials tested.

One outstanding feature shown in Table VII is that where the pollen was stored with the three diluents, powdered milk (non-fat), egg albumen and lycopodium, the viability of the pollen was maintained at a higher percentage than that of the pollen stored alone. This may be due to the diluent providing a more favorable medium for storage in regulating moisture and air relationships.

The problem of obtaining diluents for mixing with pollen is one that will require further study to make the application of pollen to fruit trees by rapid artificial means practical.

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Pollination of Native Crab Apples of the Northeastern United States

By F. C. Bradford, *U. S. Dept. of Agriculture, Glenn Dale Md.,* and R. H. Bradford, *University of Maryland, College Park, Md.*

In 1946 pollen of common apple was applied to blossoms of a native crab apple, P.I. 159890,[1] collected near Newark, Delaware, by F. L. O'Rourke, at the time in the employ of the Soil Conservation Service. After considerable injury to the earlier bloom from frost, the later blossoms set well, but their seed content was very meagre, the means from hand pollination varying between 1.0 and 1.9 per fruit. The later opening blossoms produced seedless fruit, though pollen known to be good had been applied. Of 45 open-pollinated fruits 23 were seedless and the mean was 0.98 seed per fruit. Two types of seedlings developed; either they were very vigorous and apparently replicas of the seed parent plant or they were weak, most of them dying within 2 years in the seed row. These considerations, together with several characteristics of the parent plant, as shape of leaf and blossoming season, suggested that this form was *Malus platycarpa,* as defined by McVaugh (4). According to his view this species is a hybrid between common apple and the native crab, either *M. coronaria* or *M. angustifolia.* If coronaria is the ancestor the seedlings from selfing are apogamous and seedlings from pollination with common apple would be aneuploid. Since several considerations make desirable the exploration of the possibilities of hybrids between the native species and common apple, this behavior merited further study.

Experimental work with eastern forms of the native crab is relatively meagre. Sax (6) found *Malus platycarpa* to be self-sterile. Stout (7) reported complete failure to obtain set with selfing of *M. coronaria.* Only 10 per cent of the grains germinated but those that did germinate made good growth. From the wording of the legend to the figure of *M. coronaria* it appears that Stout did not regard the finding as necessarily representing the whole species. Crandall (1, 2) had very little success in breeding from *M. coronaria.* From work on one tree, he reported (2) "from experience thus far gained it appears that want of vitality in seedling progeny is a complete bar to improvement in apple varieties through use of *M. coronaria* as the female parent in crosses". When used as pollen parent, aside from some pollinations on Stayman Winesap, a triploid variety, from 26 blossoms pollinated the net result was one seedling which "will probably reach fruiting maturity". He commented (1) on the large size of pollen grains of *M. coronaria.* Nebel (5) found *M. coronaria* to have 68 chromosomes; Lincoln and McCann (3) reported a like number for *M. coronaria* and *M. platycarpa.* Dr. Haig Dermen of the United States Department of Agriculture has informed the writers (verbal communication) that of the two platycarpas examined one was triploid

[1]Accession number of Division of Plant Exploration.

and one tetraploid and the two presumed coronarias examined were triploid.

The material available for the present study in 1949 was grown from seed collected by McVaugh (4) and for the most part it is growing where it was lined out in nursery rows in 1942. Though progenies differ considerably in growth habit, the uniformity within each progeny is striking. They are:

P. I. Number	*McVaugh Herbarium Number*	*Species*	*Collected at*
139235	5441	*Malus platycarpa*	Arlington, Va.
139237	5447	*Malus* species*	Dromgold, Pa.
139238	5448	*Malus* species*	Dromgold, Pa.
139427	5462	*Malus platycarpa*	Baltimore, Md.
139428	5473	*Malus* species*	Somerset, Pa.
139429	5481	*Malus* species*	Ridgeway, Pa.
139431	5484	*Malus* species*	Port Allegany, Pa.
139432	5485	*Malus* species*	Port Allegany, Pa.
139435	5494	*Malus* species*	Lick Brook, N. Y.
139478	5497	*Malus platycarpa*	Ballston, Va.

*Apparently *Malus coronaria*.

Also used in this study were: P.I. 127693, *Malus ioensis* from Elk River, Minn.; 127701, *M. ioensis* from Nevis, Minn.; 127712, Zafta (ioensis x Bismarck), a tetraploid; all were obtained from Hansen. Niewland (182831) is a coronaria form with double flowers (8) and with seven carpels. Arrow (148703), one of the Rosybloom series, a hybrid between *M. sylvestris* Var. *Niedzwetzkyana* and *M. baccata*, was obtained from Dr. M. B. Davis, Dominion Horticulturist, Ottawa, Ontario. The common apple was represented by: Amère de Berthecourt (127311), Foxwhelp (131598) and Knotted Kernal (131600). Except in 139235, where scarcity of bloom forced the use of three trees to represent the number, one tree of each variety was used.

After some preliminary testing, pollen was germinated in 15 per cent cane sugar in hanging drop. The results are presented in Table I, along with data on the average number of seed per fruit in the 1947 and 1948 open-pollinated crops. There were only six seedless fruits in the 1947 crop and two in the 1948 crop. There is no clear connection between

TABLE I—POLLEN GERMINATION IN 1949 AND MEAN NUMBER OF APPARENTLY GOOD SEED PER FRUIT (1947 AND 1948)

P. I. Number	Pollen Germination (Per Cent)	1947		1948	
		Number Fruits	Average No. Seed Per Fruit	Number Fruits	Average No. Seed Per Fruit
139235	52	13	3.3	65	3.9
139237	5	58	4.2	48	3.0
139238	45	—	—	27	3.7
139427	0	5	0.6	—	—
139428	10	9	3.9	77	4.6
139429	1	—	—	47	3.1
139431	40	29	3.2	52	4.7
139432	37:40	—	—	—	—
139435	25	—	—	—	—
139478	0.5	28	3.9	45	3.9
182831	26	—	—	—	—

pollen germination and seed number, such as distinguishes, in a rough way, triploid from diploid forms in the common apple. Pollen was noted at the time of extraction as especially abundant in 139235 and 139431.

A curious deviation in order of blossoming in the cluster has been repeatedly observed in both *Malus ioensis* and the northeastern forms. While the order in the common apple is from the central blossom centrifugally, in the native crabs the order is for the "terminal" blossom to open first, then the basal and so on in centripetal order.

Pollinations were made uniformly on clusters reduced to two blossoms. Twenty blossoms per cross was planned as the standard treatment; a few cases, because of accident, fell below this number, but more were slightly above. Sixty-two blossoms were used in selfing 139427; in 139431 selfing was done on 70 blossoms and 58 were devoted to its cross with 139478. For selfing of 139478 a total of 108 blossoms were used. Pollen was applied at time of emasculation; this may have reduced the set somewhat but was necessary if the whole series was to be studied. One pound paper sacks were used to cover the blossoms. Selfing was mostly without emasculation and without application of pollen. In a few cases, not included in the tabulation, blossoms were emasculated and sacked without pollination; no fruit resulted except two on 139427.

The data in Table II show definitely that two of the platycarpas tested are without value as pollenizers. This was expected in view of

TABLE II—PERCENTAGE OF SET OBTAINED WITH POLLEN OF *Malus platycarpa*, *M. coronaria*, *M. ioensis* AND *M. sylvestris*

Female Parent	Pollen Parent													
	127311	127693	127701	131600	139235	139237	139427	139428	139429	139431	139432	139478	148703	182831
127693		0	—	—	30	—	—	—	—	16	—	0	—	—
127701	—	—	0	23	23	—	—	—	—	15	—	0	—	—
127712	25	—	—	—	—	—	0	—	—	—	—	—	—	—
131598	—	—	—	—	40	—	—	—	—	—	—	—	—	—
131600	—	—	—	—	25	—	0	—	—	—	—	0	50	—
139235	30	—	—	45	16	—	—	—	—	—	—	0	—	—
139237	—	—	—	—	31	20	—	—	—	50	—	—	—	—
139427	—	—	—	—	—	—	5	—	—	—	—	—	44	—
139428	—	—	—	35	—	—	—	87	—	80	—	—	—	—
139429	—	—	—	27	55	—	—	—	60	43	—	—	—	—
139431	—	—	—	60	—	—	—	—	—	80	—	3	—	—
139432	—	—	—	—	—	20	—	—	—	—	18	—	—	—
139478	—	—	—	—	6	—	0	—	—	—	—	0	4	—
182831	—	—	—	12	—	—	—	—	—	—	—	—	—	14

their hypothetical origin. Moreover, for 139478 we have Dermen's report that it is a triploid; 139427 appears to be also a triploid. The third platycarpa, 139235, however, is a good pollenizer; it was reported by Dermen to be a tetraploid. This is not strange if we consider that this form is a hybrid of *Malus angustifolia*, which has been reported (3) to have 34 chromosomes. McVaugh mentions observing traces of *M. angustifolia* in the foliage of the parent tree.

None of the other crabs of the northeastern type tested gives evidence of self unfruitfulness, despite the poor pollen germination of

139237, 139428 and 139429. The self unfruitfulness of the two ioensis forms is in accord with Crandall's (2) findings.

There is still much to be learned about the native crab. Dermen's tentative determination of 139236, *Malus coronaria,* from Duncannon, Pennsylvania as triploid, has not been tested because of the scarcity of bloom; 139431 is still an apparent anomaly. Dermen reports it tentatively to be triploid and this is borne out by the inferior growth of the few seedlings available, but its pollen germination and its behavior as pollenizer do not square with triploidy. Finally, a lot of 34 seedlings of 139237, 139428 and 139434, the last a coronaria type from Lick Brook, New York, from pollinations with common apple, now in their second year, bear no evidence of anything but *M. coronaria;* here is suggestion of apomicty. Since most varieties of common apple are through blossoming when the coronarias begin to bloom, pollination of common apple with coronaria, except by storage of the pollen from one year to the next, is difficult.

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Five-Year Performance of Several Apple Varieties on Malling Rootstocks in Michigan[1]

By H. B. TUKEY and R. F. CARLSON, *Michigan State College, East Lansing, Mich.*

BECAUSE of the commercial interest in apple trees smaller in size than standard trees on vigorous rootstocks, and because little information is available on the performance of smaller trees under Middle Western conditions, the following preliminary data are presented. They give the record of seven varieties of apples on eight Malling rootstocks growing under Michigan conditions during five growing seasons.

MATERIALS AND METHODS

The Malling rootstocks used in these trials were raised as layers at Geneva, New York, from material secured from the East Malling Research Station in England. Nursery trees were budded on these rootstocks, and grown to 2-year size also at Geneva, New York. The combinations selected for trial were those that from previous experience (3) might be considered promising for commercial fruit production, namely, McIntosh/I, McIntosh/II, McIntosh/IV, McIntosh/V, McIntosh/VII, McIntosh/XII and McIntosh/XIII; Cortland/II, Cortland/IV, Cortland/V, Cortland/VII, Cortland/XII and Cortland/XIII; Fameuse/XII; Northern Spy/VII; Wealthy/XII and Wealthy/XVI; and Golden Delicious/XIII.

The trees were planted as 2-year-olds in the spring of 1945 at East Lansing, Michigan in 18 rows of 10 trees of the same variety and rootstock, totalling 180 trees. They were planted 15 feet apart in rows 20 feet apart so as to provide ample space for standard tillage and spraying operations.

The soil in the orchard is relatively light as compared to the heavier soils of western New York where other tests have been conducted (3). It is classified as a Hillsdale sandy loam graduating to a Granby sandy loam, the subsoil being a sandy clay. The soil is well drained, in good physical condition and generally favorable to tree growth.

The average annual rainfall in Michigan is about 30 inches, but is not well distributed during the growing season. Drouthy conditions are not uncommon in mid-summer. The rainfall during the seasons of 1945, 1947 and 1949 was above average and was relatively high during the summer months (table I). On the other hand, the summer of 1946 was one of extreme drouth, the total rainfall for July and August being only 1.13 inches, and the entire year only 23.50 inches. The rainfall in 1948 was also low, with deficiencies from July to November.

The monthly temperatures are given in Table II. As can be seen from the table, the winter temperatures during the 5-year period were not extreme. The lowest temperature was −12 degrees F in 1948. The summer temperatures too, were favorable except for relatively high temperatures in July and August in 1946 and 1948, associated with unusually dry weather during these two seasons.

[1]Journal article No. 1110 of the Michigan Agricultural Experiment Station.

TABLE I—MONTHLY PRECIPITATION FOR THE PERIOD 1945–1949 INCLUSIVE (INCHES)*

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Yearly Total
1945	0.55	1.34	2.54	3.48	7.42	3.70	2.08	6.31	6.58	2.56	1.11	1.28	38.95
1946	1.65	2.22	2.43	0.82	3.93	2.48	0.25	0.88	1.76	2.14	1.88	3.06	23.50
1947	3.39	0.84	2.82	6.39	5.22	2.74	3.06	3.86	4.75	2.68	1.99	2.00	39.74
1948	1.52	2.03	5.21	2.52	5.35	4.44	1.65	1.86	1.62	1.01	2.49	2.23	31.93
1949	3.48	2.47	2.61	1.87	2.35	4.89	4.78	1.65	1.91	—	—	—	—

TABLE II—MONTHLY MEAN MAXIMUM AND MINIMUM TEMPERATURES FOR 1945–1949 INCLUSIVE (DEGREES F)*

Year	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec		Years Lowest
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	
1945	23.3	11.0	32.3	18.5	57.7	35.2	58.5	38.2	60.3	41.7	72.5	52.6	77.8	57.1	77.7	57.7	69.3	52.2	57.6	38.0	46.3	32.3	29.3	16.5	−3
1946	32.1	18.6	32.8	15.3	55.0	34.3	58.4	35.2	65.1	43.5	75.1	54.9	82.5	59.2	76.8	54.9	74.7	50.9	67.2	44.2	49.2	33.9	38.3	22.2	−1
1947	33.8	19.2	27.5	13.8	36.2	21.8	53.7	34.0	61.7	42.5	73.5	53.7	78.0	58.3	85.3	65.0	72.0	52.8	67.8	47.8	40.8	28.4	33.1	21.4	−1
1948	24.2	9.3	31.3	14.7	42.7	23.6	60.9	39.8	64.7	43.7	75.0	54.7	83.6	60.8	83.1	58.5	76.7	53.6	58.5	37.9	49.1	36.7	35.1	22.3	−12
1949	35.6	20.6	34.6	20.1	42.1	25.6	57.4	35.1	71.6	47.4	82.6	60.8	84.8	63.4	81.8	58.7	61.1	47.3	—	—	—	—	—	—	—

*Weather data furnished by the Weather Bureau of the United States Department of Commerce, Lansing, Michigan.

The orchard was well sprayed during the five seasons according to standard spray programs and was free from insect and disease troubles. The trees were pruned when planted but no pruning was done thereafter except for the removal of an occasional misplaced branch or shoot.

Clean cultivation was practiced each year until August, when a cover crop of oats and buckwheat were sown. The cover crop was grown so as to help mature the trees and to provide a rough cover during the winter. It was disced into the soil as early as possible each spring. Nitrate of soda was applied at the rate of 1 to 3 pounds to each tree just as growth was beginning each spring.

Results

General Observations:—From 180 trees planted all grew and survived the first season. Except for the destruction of six trees by tillage equipment in 1946, all trees were alive and growing well at the end of five seasons. In comparison with standard commercial nursery trees on seedling rootstocks, the growth and survival were outstanding. No incompatibilities or uncongenialities were observed (4). The trees in each stock-scion combination were remarkably uniform as recorded in trunk diameter and height, spread, and general conformation. They were likewise similar in precocity and degree of blossoming and fruit-

TABLE III—Trunk Circumference (6 Inches Above Ground), Height, and Width of Eighteen Stock-Scion Combinations of Apple Trees at Completion of Five Season's Growth (Average of Ten Trees)

Malling Rootstock	Trunk Circumference (Cm)	Tree Height (Feet)	Tree Spread (Feet)	Remarks
		McIntosh		
I	25.5	8.6	8.0	Upright
II	25.4	8.4	8.2	Upright
IV	25.4	9.0	8.5	Upright
V	26.9	9.5	8.0	Upright
VII	25.3	7.2	8.0	Upright
XII	28.2	11.2	9.6	Upright
XIII	27.7	9.2	9.0	Upright
		Cortland		
II	26.2	9.2	9.5	Spreading
IV	27.0	8.2	10.0	Spreading
V	23.2	10.8	10.5	Spreading
VII	23.1	6.2	7.5	Spreading
XII	26.1	11.0	9.5	Spreading
XIII	25.2	8.9	9.0	Spreading
		Fameuse		
XII	25.7	9.0	7.0	Upright
		Golden Delicious		
XIII	25.3	9.0	8.0	Upright
		Northern Spy		
VII	25.2	9.2	7.5	Upright
		Wealthy		
XII	24.9	11.0	8.0	Upright
XVI	23.0	11.0	8.2	Upright

ing and in habit of fruiting. There was no injury or retarded growth from either the winter cold or summer heat or drouth experienced. Severe winds in September of 1947 caused no disturbance except in the case of trees on Malling IV which blew over to some degree and required staking (1). The conditions provided give additional information on the range of adaptability of the Malling apple rootstocks.

Tree Size:—In Table III are given the trunk circumference, height, spread, and general shape of the trees. In general, the size relationships between the various stock-scion combinations are similar to those reported in New York (3) and New England (2). They are presented graphically in Figs. 1 and 2.

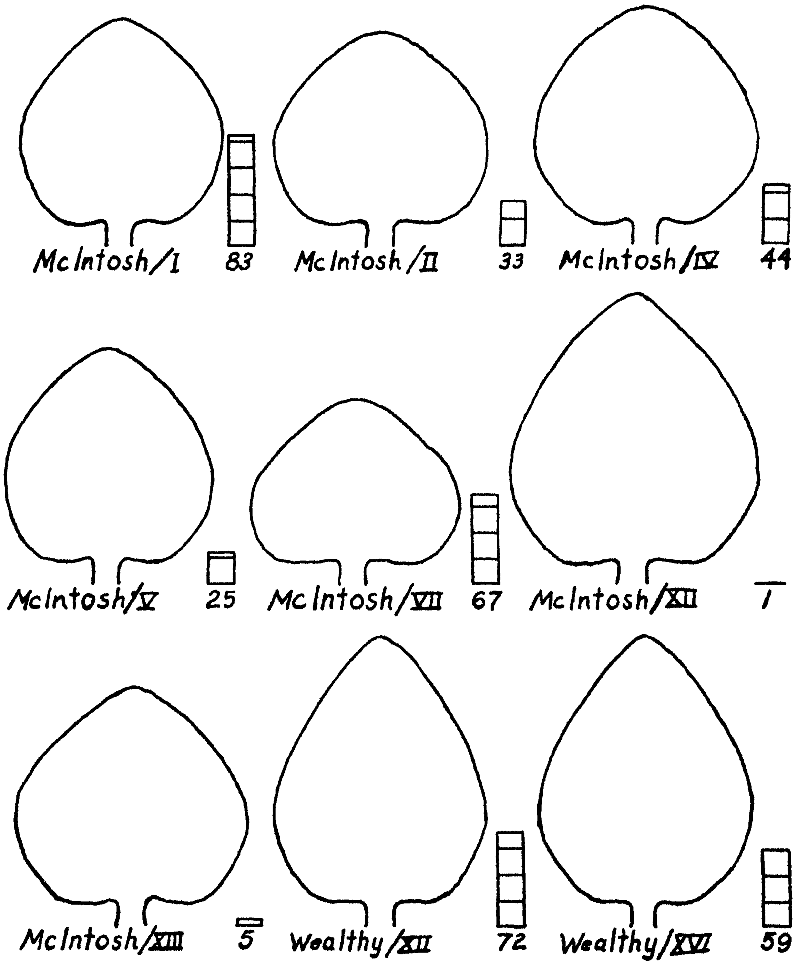

FIG. 1. Comparative size of trees propagated on different Malling stocks with total yield (pounds) of 5-year-old trees.

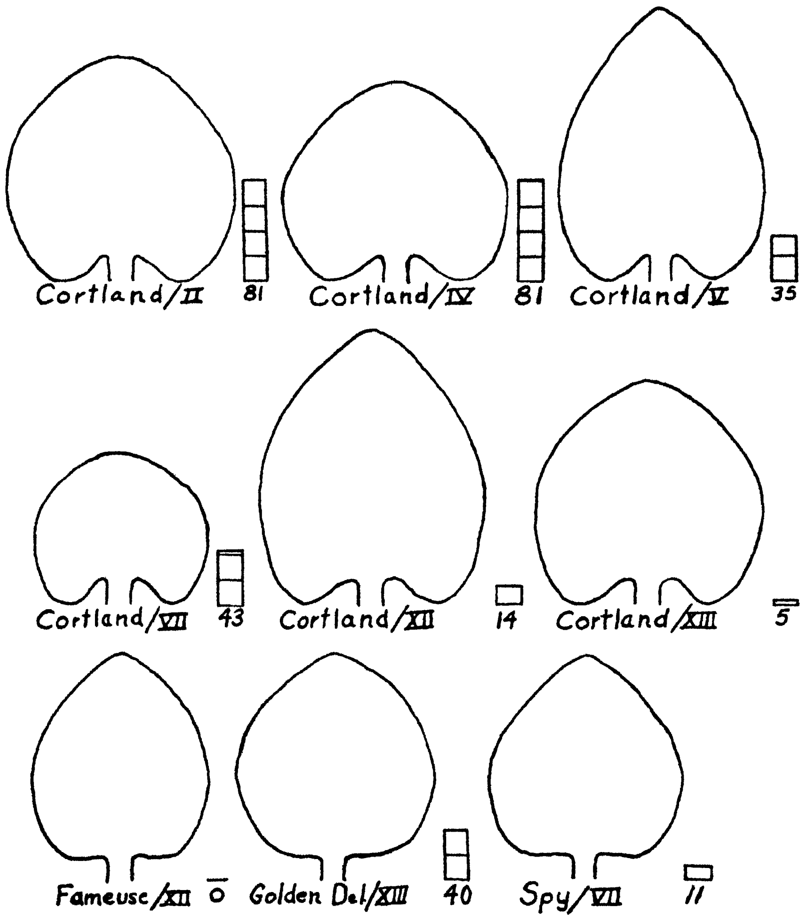

FIG. 2. Comparative size of trees propagated on different Malling stocks with total yield (pounds) of 5-year-old trees.

With the McIntosh variety, the largest trees were those on the Malling XII rootstock, followed closely by those on Malling XIII. Next smaller, but not widely different from each other, were trees on V, IV, I and II in descending order. Trees on Malling VII were the smallest of all.

With the Cortland variety, the largest trees were again those on the Malling XII rootstock, followed by those on II, IV, XIII, and V in that order. The smallest trees again, were on the Malling VII rootstock.

Northern Spy, which is a strong-growing variety was larger on Malling VII than were either McIntosh or Cortland on this rootstock. On the other hand, the relatively weaker growing Wealthy variety

was smaller on Malling XII than were either McIntosh, Cortland, or Fameuse.

Blossoming:—The records of blossoming, shown in Table IV, follow closely an inverse relation to size of tree as shown in Table III. That is, the more precocious stock-scion combinations were generally the smaller trees. Trees on Malling VII were most precocious, followed by those on I, II, IV, V, XIII and XII in that order. However, there was a tendency for Golden Delicious on Malling XIII to be relatively earlier than McIntosh on this same rootstock and Spy on Malling VII came into blossoming comparatively early.

TABLE IV—FLOWERING AND YIELD OF EIGHTEEN STOCK-SCION COMBINATIONS OF APPLE TREES IN MALLING ROOTSTOCKS, PLANTED IN 1945 (AVERAGE OF TEN TREES)

Malling Rootstock	Flowering 1947	Flowering 1948	Flowering 1949	Yield (Pounds) 1947	Yield (Pounds) 1948	Yield (Pounds) 1949	Yield (Pounds) Total
			McIntosh				
I	L*	L	F	2.0	2.8	78.5	83.3
II	L	L	M	3.2	2.6	27.8	33.6
IV	O	L	F	0.0	0.2	44.2	44.4
V	O	L	M	0.0	0.1	25.1	25.2
VII	VL	M	F	0.0	7.1	59.6	66.7
XII	O	O	L	0.0	0.0	1.2	1.2
XIII	O	O	L	0.0	0.0	3.5	3.5
			Cortland				
II	L	M	F	9.6	10.3	61.2	81.1
IV	O	L	F	0.0	2.3	78.4	80.7
V	VL	M	F	0.0	4.2	31.3	35.5
VII	L	M	F	1.7	10.2	30.9	42.8
XII	O	L	M	0.0	0.0	14.1	14.1
XIII	O	L	M	0.0	0.3	5.1	5.4
			Fameuse				
XII	O	O	L	0.0	0.0	0.7	0.7
			Golden Delicious				
XIII	VL	O	M	0.0	0.0	40.7	40.7
			Northern Spy				
VII	O	O	L	0.0	0.0	11.2	11.2
			Wealthy				
XII	VL	O	M	0.0	0.0	72.4	72.4
XVI	O	O	M	0.0	0.0	59.0	59.0

* O = No flowers.
L = Few flowers.
VL = Very few flowers.
M = Medium flowering.
F = Full flowering.

Fruiting:—The yields of fruit, shown in Table IV, parallel closely the blossoming record and are likewise in inverse relation to size of tree. They are presented graphically in Figs. 1 and 2. Again Malling VII, I, and II tended to produce the most precocious fruiting, followed by IV, V, XIII and XII. Yet it is not possible to generalize more freely. Each scion exhibited characters peculiar to itself. Thus, McIntosh/I bore more heavily at an earlier age than did any other of the McIntosh combinations, with McIntosh/VII next, followed by McIn-

tosh/IV. Yet with the Cortland variety the performance on Malling IV and Malling VII were reversed, that is Cortland/IV bore more heavily the fifth year in the orchard than did Cortland/VII. This difference is associated with the fruiting habits of these two varieties. The McIntosh tends to form a heavy spur system which bears a heavy crop of fruit once the system is established. Cortland on the other hand carries considerable of its crop terminally.

Cortland/XIII was slower to come into bearing under Michigan conditions than under New York conditions (3). On the other hand Golden Delicious appeared a precocious fruiting variety on Malling XIII.

The Wealthy variety, which is characteristically early-bearing, was early-bearing on both Malling XII and Malling XVI.

The tendency for trees on Malling IV to exhibit poor anchorage and to be blown over by strong winds is in agreement with other reports (1) and definitely limits the usefulness of this rootstock.

Malling VII produced a small and precocious tree. Even the late-bearing Northern Spy, bore fruit the fifth year. This rootstock seems useful where trees are desired which are decidedly small and early-bearing but which are more substantial than those on Malling IX.

Summary

Eighteen stock-scion combinations of apple trees on Malling rootstocks, involving 180 trees, responded favorably to growing conditions in Michigan on a relatively light soil and during two drouthy seasons. They grew vigorously and developed and fruited in about the same relationships as observed in other locations in eastern United States. In size, the largest trees were those on Malling XII, followed in descending order by Malling XIII, then by a group comprising Malling V, IV, I, and II, with trees on Malling VII the smallest. In blossoming and fruiting precocity was in reverse order, with the earliest-bearing on the Malling VII rootstock, followed by Malling I and II, which in turn were followed by Malling IV, V, and XIII, with Malling XII the most tardy. Malling XIII appeared a precocious rootstock for Golden Delicious but relatively less so for Cortland. Malling VII produced both small and early-bearing trees which are more substantial than trees on Malling IX. Cropping is associated with the bearing habits of the variety, in which McIntosh bears heavily on strong spur development and Cortland less heavily on terminals.

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Sixteen Years' Results of Orchard Tests with Apple Trees on Selected Rootstocks, Kearneysville, W. Va.[1]

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THIS report presents additional results of apple rootstock research conducted at Kearneysville, West Virginia, by the West Virginia Agricultural Experiment Station. The particular planting covered by this report is designated as block A.

While the first paper (2) should be consulted for more complete details, a very brief review of the more essential facts is given here.

In this orchard, the scion varieties, Gallia Beauty, Starking, Staymared, and York Imperial, were budded both on seedling and on clonal rootstocks.

The seedling rootstocks were from open-pollinated seed from the varieties Delicious, Grimes Golden, Jonathan, McIntosh, Northern Spy, Rome Beauty, Wealthy, and Winesap. French Crab also was represented in this orchard.

The clonal rootstocks were the clone Northern Spy; East Malling I, XIII, and XV; and five clones from the United States Department of Agriculture, designated by the numbers 313, 316, 317, 323, and 329.

The trees were planted 20 by 20 feet apart in units of six trees on each rootstock and with a few exceptions these units were distributed in four places in the orchard. Rootstocks 316 and 329 were in alternate third rows to serve as standards with which to compare the others. In the majority of the scion-rootstock combinations, the original 24 trees were reduced by losses, but in some combinations the number remained until the fillers of the Starking, Staymared, and York Imperial varieties were removed in the winter of 1941–42. The fillers of the Gallia Beauty variety were cut after the 1942 season. As block A stood in 1948, the greatest possible number of trees of any of the combinations other than 316 and 329 was 12, a figure attained only in occasional instances.

During the dormant season following the 1948 crop, the semi-permanent trees were removed except in the Gallia Beauty sections in which crowding was not yet a problem. For this reason, there will be no more records of any sort from block A for Starking, Staymared and York Imperial worked on 316, 313, East Malling I, among the clones. With the seedling rootstocks, Jonathan, Wealthy, McIntosh, Rome Beauty, and Northern Spy worked to the same three scion varieties have also disappeared. The experimental layout of block A has been disappointing in certain respects. Not the least of the shortcomings is the planting plan which uses as semi-permanents scion-rootstock combinations not available in the permanents. In removing the semi-permanents, therefore, half of the rootstocks have been lost, including some of the most interesting ones, while several worthy of

[1]Published with the approval of the Director, West Virginia Agricultural Experiment Station, as Scientific Paper, No. 412.

discard have to be retained simply because of position in order to have a more or less regularly planted orchard with no "border effects".

YIELDS THROUGH THE 1948 SEASON

Table I presents the average total yield per tree for all varietal and rootstock combinations from the initiation of bearing through the 1948 season in comparison with the yields of the adjacent trees on 329.

Of the four varieties in block A, Starking and Gallia Beauty are least sensitive to rootstock effects while Staymared and York Imperial are most affected.

Starking:—The yields of the Starking trees are still the lowest of all four varieties. This need occasion no surprise.

After the 1948 crop, only Starking/Delicious and Starking/East Malling XIII were significantly lower in production than the comparisons on 329.

Starking/Jonathan has lost its former significantly superior yield over Starking/329, as has Starking/317.

The other Starking/rootstock combinations hold about the same relative ranks as in 1944 (1), when the previous report was published. Some have tended to rise and others to fall, but the high standard errors render most of the changes insignificant.

Gallia Beauty:—The Gallia Beauty trees have continued unexpectedly to hold their lead in production over the other three scion varieties, this in spite of their generally smaller tree size.

The only significant differences between the various combinations is with Gallia Beauty/East Malling I and Gallia Beauty/Jonathan; both of which have produced significantly less than the Gallia Beauty/329 comparisons.

Gallia Beauty/317 and Gallia Beauty/323 have both lost their formerly significant margins over Gallia Beauty/329.

York Imperial:—York Imperial/317 and York Imperial/323 have both lost their significant superiority over York Imperial/329.

York Imperial/French Crab, after 1944 significantly lower in yield than York Imperial/329, no longer holds that low position. On the other hand, York Imperial/Rome Beauty and York Imperial/East Malling XIII are both significantly inferior in yield to 329. Trees on Grimes Golden seedlings, Northern Spy clone and East Malling I are dwarf trees with very poor yields. This development was evident practically from the beginning of their orchard life.

Other than the few instances discussed, the relative ranks and significances have remained much the same.

Staymared:—Staymared/Northern Spy Clone has lost its 1944 superiority over 329. No rootstock now exceeds 329 in yield when budded to Staymared.

Worked to Staymared, East Malling XV, French Crab, Wealthy, Delicious, 313, and Winesap have significantly lower yield records than 329 through 1948. All of these significances have developed since 1944.

Also with Staymared, East Malling XIII, Grimes Golden, Rome Beauty, and McIntosh continue their relatively low yields as compared with Staymared/329.

Other combinations show no significant changes.

Trunk Circumference After the 1948 Season

Table II presents the average trunk circumferences after the 1948 season for each varietal and rootstock combination in comparison with the circumferences of the adjacent trees on 329.

The trunk circumferences have not varied nearly as widely as have the yields. In numerous instances, there are significant differences in trunk circumferences between the same variety on 329 and on a particular rootstock with which yields fail to give a significant difference.

A comparison of Tables I and II will show that while there is a tendency for a heavier yielding combination to have a larger trunk circumference and, inversely, for a lighter producer to have a smaller girth, such generalizations do not always hold true for a specific instance.

TABLE I—Average Total Yields in Pounds Per Tree of 16 Year-Old Apple Trees on Known Rootstocks at Kearneysville, West Virginia (Trees on Each Rootstock Compared With Those on Adjacent No. 329 Rootstock as Standard)

Rootstocks	N*	M	D	S.E.D.	Rootstocks	N*	M	D	S.E.D.
Gallia Beauty					*Starking*				
McIntosh (s)	7	3,142	+686	652.0	E.M.XV (c)	8	1,374	+405	263.5
316 (c)	36	2,863	+542	144.4	Wealthy (s)	8	1,262	+293	291.0
317 (c)	10	2,978	+522	291.2	Jonathan (s)	8	1,234	+265	283.1
E.M. XV (c)	12	3,355	+376	618.7	317 (c)	9	1,416	+188	199 4
323 (c)	10	2,510	+323	369.8	313 (c)	6	1,304	+112	220.3
Rome (s)	9	2,414	− 42	296.9	E.M. I (c)	11	1,169	+ 75	150.7
E.M. XIII (c)	5	2,375	− 80	281.7	316 (c)	32	1,150	+ 9	104 2
Winesap (s)	8	2,013	−139	294.1	N. Spy (c)	12	1,125	− 67	203 4
313 (c)	11	1,986	−166	220.6	323 (c)	9	1,013	− 81	171.5
Delicious (s)	11	2,003	−184	215.5	McIntosh (s)	10	1,125	−103	194.8
Grimes (s)	10	2 133	−323	198.3	N. Spy (s)	9	965	−227	191.1
N. Spy (s)	10	1,815	−337	253.3	Fr. Crab (s)	8	706	−263	261.1
N. Spy (c)	10	1,720	−432	218.8	Rome (s)	11	925	−303	168.7
E. M. I (c)	7	1,672	−515	229.0	Grimes (s)	9	896	−332	239.3
Jonathan (s)	9	2,448	−531	323.3	Winesap (s)	7	843	−349	297.1
Fr. Crab (s)	11	2,051	−928	315.0	Delicious (s)	9	743	−351	147.8
Wealthy (s)	9	1,973	−1,006	1,075.0	E. M.XIII (c)	7	671	−423	153.4
Staymared					*York Imperial*				
N. Spy (s)	10	2,088	+202	141.4	317 (c)	12	2,738	+283	217.4
N. Spy (c)	11	2,031	+145	179.4	323 (c)	10	2,315	+ 28	174.8
E.M. I (c)	9	2,087	+ 95	201.1	316 (c)	41	2,288	− 11	119.8
316 (c)	39	2,223	− 86	140.6	Wealthy (s)	8	2,356	− 51	218.5
Jonathan (s)	11	2,455	−139	217.3	313 (c)	9	1,909	− 53	274.4
323 (c)	11	1,762	−230	200.1	N. Spy (s)	6	1,895	− 67	300.2
E.M. XV (c)	9	2,287	−307	160.3	Fr. Crab (s)	11	2,315	− 92	272.2
Fr. Crab (s)	12	2,205	−389	199.4	Jonathan (s)	11	2,305	−102	244.0
Winesap (s)	10	1,454	−432	192.0	McIntosh (s)	5	2,348	−107	165.1
317 (c)	9	2,378	−443	236.1	E.M. XV (c)	11	2,142	−265	201.5
Wealthy (s)	11	2,085	−509	172.0	Winesap (s)	4	1,648	−314	219.7
E.M. XIII (c)	9	1,436	−556	168.3	Delicious (s)	6	1,801	−486	211.1
Delicious (s)	9	1,406	−586	238.4	Rome (s)	9	1,954	−501	171.1
313 (c)	9	1,296	−590	164.1	Grimes (s)	9	1,655	−800	202.9
Grimes (s)	7	2,105	−716	219.5	E.M. XIII (c)	8	1,444	−843	300.4
Rome (s)	7	2,011	−810	254.9	N. Spy (c)	5	865	−1,097	281.0
McIntosh (s)	3	1,953	−868	316.3	E.M. I (c)	10	731	−1,556	146.3

*N = number of trees; M = average total yield in pounds per tree (from start of bearing through the 1948 season). D = differences from the yield of the given variety on 329 rootstock. S.E.D. = standard error of the differences. (c) = clone. (s) = seedling.

TABLE II—AVERAGE TRUNK CIRCUMFERENCES IN MILLIMETERS OF 16-YEAR-OLD APPLE TREES ON KNOWN ROOTSTOCKS AT KEARNEYSVILLE, WEST VIRGINIA (TREES ON EACH ROOTSTOCK COMPARED WITH THOSE ON ADJACENT NO. 329 AS STANDARD)

Rootstocks	N*	M	D	S.E.D.	Rootstocks	N*	M	D	S.E.D.
		Gallia Beauty					*Starking*		
Jonathan (s)	9	693	+ 1	27.3	Jonathan (s)	8	919	+75	58.6
McIntosh (s)	7	695	−11	23.3	Fr. Crab (s)	8	869	+25	46.6
Fr. Crab (s)	11	679	−12	30.9	Delicious (s)	9	865	+16	53.9
Rome (s)	9	691	−14	33.9	E M. XV (c)	8	837	−7	48.4
E.M. XV (c)	12	676	−15	17.9	Wealthy (s)	8	822	−21	40.9
Delicious (s)	11	694	−17	20.8	E.M. I (c)	11	826	−22	41.8
316 (c)	36	688	−18	13.4	313 (c)	6	871	−23	36.3
323 (c)	10	689	−22	35.5	316 (c)	32	868	−29	22.4
317 (c)	10	680	−26	25.3	N. Spy (s)	9	860	−34	31.4
Grimes (s)	10	677	−29	20.7	Winesap (s)	7	841	−53	59.5
E.M. XIII (c)	5	674	−37	26.5	Rome (s)	11	895	−62	38.4
Winesap (s)	8	677	−40	13.1	323 (c)	9	770	−78	59.5
N. Spy (s)	10	652	−66	54.3	N. Spy (c)	11	809	−85	29.7
313 (c)	11	649	−68	36.3	E.M. XIII (c)	6	751	−97	64.5
Wealthy (s)	9	615	−77	31.1	Grimes (s)	9	844	−113	40.3
E.M. I (c)	7	605	−106	44.2	317 (c)	9	841	−116	41.1
N. Spy (c)	10	582	−135	44.1	McIntosh (s)	10	791	−166	29.4
		Staymared					*York Imperial*		
E.M. I (c)	9	779	−45	27.0	Winesap (s)	4	825	+7	27.2
323 (c)	11	772	−52	25.8	Jonathan (s)	11	856	0	33.3
Grimes (s)	7	867	−52	30.1	E.M. XV (c)	11	837	−18	25.1
Winesap (s)	10	790	−59	25.3	Fr. Crab (s)	11	835	−20	31.3
N. Spy (s)	10	790	−59	25.7	McIntosh (s)	5	835	−31	36.8
Jonathan (s)	11	828	−75	36.6	317 (c)	12	828	−38	20.7
E.M. XIII (c)	9	744	−80	28.4	316 (c)	41	815	−40	14.1
Delicious (s)	9	741	−83	31.6	N Spy (s)	6	775	−41	44.7
316 (c)	39	790	−83	16.8	Rome (s)	9	821	−44	81.4
Rome (s)	7	818	−102	27.4	Wealthy (s)	8	792	−63	33.3
Fr. Crab (s)	12	800	−103	34.9	Delicious (s)	6	793	−87	34.0
N. Spy (c)	11	743	−106	25.4	E.M. XIII (c)	8	789	−90	30.5
E.M. XV (c)	9	779	−124	32.9	323 (c)	10	780	−100	23.3
Wealthy (s)	11	777	−125	33.6	313 (c)	9	708	−109	47.3
317 (c)	9	791	−129	31.3	N. Spy (c)	5	643	−174	56.8
313 (c)	9	714	−135	21.0	Grimes (s)	9	674	−192	36.3
McIntosh (s)	3	764	−155	43.0	E.M. I (c)	10	55	−324	22.4

*N = number of trees; M = average trunk circumferences in Mn. D = differences from the circumference of the given variety on 329 rootstock. S.E.D. = standard error of differences. (c) = clone (s) = seedling.

For example, Staymared/Grimes Golden has a mean trunk circumference at least as large as on 329. With yields, Staymared/Grimes Golden is significantly lower than Staymared/329.

It had been planned to obtain the top weights of the semi-permanents as they were removed. Unfortunately, the platform scales needed were not supplied before the funds became unavailable. These valuable data were therefore not obtained.

A DISCUSSION OF CERTAIN ROOTSTOCKS

The differential behavior of two or more of the scion varieties when worked on certain of the rootstocks in block A stresses once more the necessity of testing every combination of varieties and rootstock before making any recommendations for combining that pair. This is nothing new, but it is an item too often overlooked in practice. Generalizations with rootstocks are dangerous, unless they are backed by adequate research:

For example, Starking/Wealthy and York Imperial/Wealthy have yielded as well as those two varieties on 329. On the other hand, Gallia

Beauty/Wealthy is at the bottom of the list with a low yield and a very erratic record. With Staymared/Wealthy, the yield is significantly lower than that of the same variety on 329.

The use of seed from Northwestern apple byproducts plants for the production of seedling rootstocks continues to be a questionable practice if the indications obtained from block A are valid. This seed would be chiefly from fruit of the Delicious and Winesap varieties. In this experiment only with Gallia Beauty have Delicious seedlings equalled the production of the trees on 329. Staymared/Winesap has a significantly lower yield than Staymared/329. Only with Gallia Beauty have the Winesap seedlings yielded satisfactorily.

The two rootstocks, 316 and 329, which were employed as standards in planning block A, have very similar yield records when worked to three of the four varieties. Only with Gallia Beauty is there any significant difference in yield. This is in favor of 316 over 329.

French Crab is still a seedling rootstock that can well be left out in considering needs of the apple orchards of the future. There has been nothing in the performance of French Crab in this orchard to suggest that its use be recommended in nurseries of the United States. It is recognized that every lot of French Crab seed may be of different origin and produce seedlings of quite varying growth characteristics.

The size of the standard errors of the difference, especially in yield, suggests that influences other than stock and scion are the greater. It is doubtful, however, if this is always the case.

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Occurrence of Certain Diseases in Sweet Cherry Seedlings Propagated on Stockton Morello Rootstocks

By Reid M. Brooks and William B. Hewitt, *University of California, Davis, Calif.*

The breeding work with sweet cherries has been in progress at the University of California Agricultural Experiment Station since 1935, with some thousands of seeds resulting from numerous crosses. Very few of these seeds germinated because of the difficulties encountered in the handling of embryos of early-maturing varieties. Experience and refinement in technique resulted in a large number of plants in 1941 that had to be taken care of the following year. In order to propagate these seedlings and to evaluate the fruit of them as soon as possible, it was decided to bud each seedling on vegetatively propagated Stockton Morello, a clone of *Prunus cerasus*. This clone is known to dwarf trees and has been used successfully in California as a rootstock for the growing of sweet cherry varieties in heavy soils.

Nursery trees produced from rooted suckers of Stockton Morello were secured from a nurseryman. A bud from each seedling tree was placed in an individual Stockton Morello tree in August 1941; the trees were transplanted from the nursery to the orchard in January 1942. Some of these budded seedling trees fruited in 1946, a few more in 1947, and the majority of them produced sizable crops in 1948. In 1946 it was noticed by the late Professor Guy L. Philp, who had been in charge of the cherry breeding project since its inception at this Station, that several of the trees were showing disease.

Symptoms similar to a new disease of sweet cherries first reported in California in 1946 by Milbrath (3) and later referred to as "blister" by Allstatt (1) were observed in a few trees in this block in the spring of 1947. During the following spring and early summer, the entire block of 726 trees, representing 54 crosses, was examined and mapped for various diseases (Table I). The most important disease found was cherry blister.

Blister:—The symptoms of cherry blister have some characters in common with those described from Utah under the name of rusty mottle by Rhoads (6, 7), by Richards and Rhoads (8), and a rusty mottle-like disease by Reeves and Richards (5). The disease is gen-

TABLE I—Diseases and Number of Cherry Trees Infected in a Seedling Orchard Propagated on Stockton Morello, Davis, Cali-

Disease	Number of Crosses Showing the Disease	Number of Infected Trees
Blister	24	162
Fasciation or witches broom	4	25
Crinkle leaf	13	23
Pinto leaf mosaic	1	2
Big node	1	2
	Diseased trees	214 = (29.4 per cent)
	Clean trees	512 = (70.6 per cent)
	Total	726

erally considered[1] distinct from the rusty mottle described by Reeves (4) in Washington and mild rusty mottle described by Zeller and Milbrath (10) from Oregon. Leaves of some trees showed yellowing with rings of green tissue, varying degrees of chlorotic mottling and premature leaf fall. Leaves of other trees showed rusty spots and varying amounts of necrotic spots which often fell out leaving a shot hole effect. Many of the trees had leaves which showed only the symptom of chlorotic spots that became necrotic. These latter symptoms usually appeared in leaves extending from varying positions on the new shoots to the growing tips.

Diseased trees, often sparse in foliage, showed wilting and often dying and sloughing of fruiting spurs along the larger branches leaving the branches with foliage principally at the extremities.

In addition many of the trees had blisters of varying sizes in the bark along the limbs. These blisters were found most prevalent along the branches which had leaves with necrotic spots.

Two varieties of sweet cherries, Bing and Lambert planted in this block, were propagated on some of the same lot of Stockton Morello rootstock. These developed varying degrees of cherry blister symptoms even though the original trees from which the propagating wood was taken have remained free of disease symptoms. The parent trees of all the crosses showed no apparent symptoms of this disease. The propagating wood was taken from the seedlings in the nursery and budded directly on the Stockton Morello rootstock. This evidence indicates that the occurrence of this disease in this large number of sweet cherry seedlings and the two named varieties was definitely linked to the particular source of the vegetatively propagated Stockton Morello rootstock upon which they were growing.

Table II shows the crosses in which symptoms of the disease have developed and the incidence of the disease in each cross. The wide variation in type of symptoms shown by the seedlings of these crosses suggest that possibly the degree of symptom expression may be due to seedling variation and not due to variation in the causal agent.

Table III shows the crosses in which no symptoms of disease were observed.

Fasciation or Witches Broom:—This was the next most prevalent trouble that appeared in this block of 726 sweet cherry trees. Twenty-five of the trees showed varying degrees of fasciation. They have not been classified critically as to the types given by White (9). Table IV gives the crosses and incidence of fasciation in them; it is readily discovered that either Bing or A–10 or both were parents of the fasciated seedlings. These represent five crosses out of the 54 under consideration propagated in this block.

On affected trees flower and fruit production was almost nil. In only two trees were flowers produced in a sufficient quantity (estimated at 30 per cent of a normal bloom) and in only one tree did the crop amount to a few pounds of fruit. The usual situation was the production of 3 to 10 fruits per tree.

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[1]As noted in a letter from L. C. Cochran.

TABLE II—PARENTAGE AND NUMBER OF CHERRY SEEDLINGS SHOWING BLISTER

Cross	Number of Seedlings		
	Blister	Clean	Total
A-10 × California 2 (Bing × Sanguinetti)	1	2	3
A-10 × Bing	15	38	53
A-10 × Bush Tartarian	8	29	37
A-10 × Napoleon	26	95	121
A-10 × Ord	29	105	134
Bedford × Bush Tartarian	2	10	12
Bedford × Coops	2	13	15
Bing × A-10	10	18	28
Bing × Bedford	10	34	44
Bing × Bush Tartarian	2	2	4
Bing × Early Rivers	1	4	5
Bing × California 46 (Lambert × Bush Tartarian)	1	1	2
Bush Tartarian × Early Rivers	1	0	1
Giant × Long Stem Bing (Napa Selection)	6	7	13
La Cima × A-10	3	3	6
La Cima × Bassford	1	5	6
La Cima × Bush Tartarian	4	14	18
La Cima × Oxheart	1	0	1
La Cima × Windsor	1	1	2
Lambert × A-10	7	22	29
Lambert × Long Stem Bing (Napa Selection)	19	30	49
Lambert × Deacon	2	0	2
Lambert × Ramon Oliva	6	22	28
Napoleon × A-10	2	8	10
Napoleon × Bigarreau Blanc	1	0	1
Saylor × Early Rivers	1	6	7
Totals	162	469	631

TABLE III—PARENTAGE AND NUMBER OF SEEDLINGS WHICH SHOWED NO APPARENT SYMPTOMS OF DISEASE IN 1948

Cross	Total Number of Seedlings
A-10 × Emperor Francis	6
Bing × Long Stem Bing (Wheatley Selection)	2
Emperor Francis × A-10	2
English Morello × May Duke	1
La Cima × Belle d'Orleans	3
La Cima × Chapman	3
La Cima × Coops	2
La Cima × Lewelling	2
La Cima × Pontiac	2
Lambert × Chapman	1
Lewelling × Lambert	1
Napoleon × California Selection 6 (Bing × Sanguinetti)	4
Napoleon × California Selection 27 (Napoleon × Bush Tartarian)	1
Napoleon × California Selection 48 (Bing × Bush Tartarian)	2
Napoleon × Bedford	8
Napoleon × California Selection 46 (Lambert × Bush Tartarian)	1
Napoleon × Mezel	2
Ord × A-10	4
Ord × Napoleon	1
Ord × Ramon Oliva	2
Saylor × Bassford	3
Saylor × Chapman	3
Saylor × Ord	1
Windsor × Coops	2
Windsor × Schmidt	1

The very low incidence of fasciation in the seedlings and their being limited to the crosses involving only Bing, A-10 and Ord suggests that this condition has arisen as a result of the cross and is not necessarily associated with the rootstock. This seems most likely even though no transmissibility tests have been made nor did any of the parent trees show any signs of the condition.

TABLE IV—PARENTAGE AND NUMBER OF SEEDLINGS SHOWING FASCIATION IN 1948

Cross	Number of Seedlings		
	Fasciated	Clean	Total
A-10 × Bing	8	45	53
A-10 × Bush Tartarian	2	35	37
A-10 × Ord	1	133	134
Bing × Bedford	10	34	44
Bing × A-10	4	24	28
Total	25	271	296

Crinkle Leaf:—Twenty-three seedlings representing 11 of the 54 crosses showed signs of this trouble (Table V). Some of these seedlings are the result of crosses made to examine this genetic relationship in some detail. No effort has been made to associate this trouble with the rootstock. In 1942, 8000 crosses were made with Napoleon as the pistillate parent, using pollen from a Black Tartarian tree showing crinkle leaf and pollen from a crinkle-free Black Tartarian tree (Chandler selection); 87 seeds resulted with only seven seedlings germinating. Two seedlings displayed crinkle leaf in the 1948 survey as noted in the last two items of Table V.

TABLE V—PARENTAGE AND NUMBER OF SEEDLINGS SHOWING CRINKLE LEAF IN 1948

Cross	Crinkle	Clean	Total
A-10 × Bing	5	48	53
A-10 × Bush Tartarian	2	35	37
A-10 × Napoleon	2	119	121
Bedford × Bush Tartarian	1	11	12
Bing × A-10	4	24	28
Bing × Bedford	4	40	44
Bing × Bush Tartarian	1	3	4
Bing × Sangumetti	1	1	2
Giant × Long Stem Bing (Napa Selection)	1	12	13
Napoleon × Black Tartarian (Chandler Selection)	1	0	1
Napoleon × Black Tartarian (Crinkle Leaf Selection)	1	4	5
Totals	23	297	320

One crinkle leaf tree (from an A–10 x Bush Tartarian cross) showed rusty spots and blister symptoms.

In 1943, 6000 crosses were made which resulted in 507 seeds from which only one seedling arose. This was from a Napoleon x Mezel (crinkle leaf) cross and has shown no crinkle.

Earlier observations of crinkle leaf were made in 1944 by Philp and Hewitt on selections that had been propagated on old Napoleon trees. These crosses and incidence of disease are shown in Table VI from which it is noted that crinkle leaf appears to a greater extent in crosses with Bing as a parent than in any other population. These results add a little more evidence to the possibility that crinkle leaf or susceptibility to it is a genetic phenomenon.

Other Diseases:—A disease similar to pinto leaf mosaic as described by Kienholz (1) was found in two trees in this seedling block in a cross

TABLE VI—PARENTAGE AND NUMBER OF SEEDLINGS SHOWING CRINKLE LEAF IN 1944 (FROM PHILP'S NAPOLEON SELECTION BLOCK)

Cross	Infected	Clean	Total
Bing × Sanguinetti	8	17	25
Bing × Bush Tartarian	2	54	56
Lewelling × Deacon	1	6	7
Napoleon × Sanguinetti	1	2	3
Total	12	79	91

of Bedford x Bush Tartarian. Two other trees displayed big node which, as the name indicates, is characterized by an excessive enlargement of the tissue about the individual nodes; these were found in the cross La Cima x Bush Tartarian.

SUMMARY

A block of 726 sweet cherry trees mostly seedlings representing 54 crosses, propagated on Stockton Morello rootstock were examined for various diseases; 162 trees showed varying degrees of the cherry blister disease; 25 trees showed fasciation or witches broom; 23 of the trees showed cherry crinkle leaf; 2 trees showed symptoms similar to pinto leaf mosaic; and 2 a condition called big node.

It appears that the cherry blister disease resulted from transmission to the scion from the rootstock, and that the fasciations and crinkle leaf both developed as a result of hybridization. No attempt is made to explain the presence of the pinto leaf mosaic and big node.

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Rootstock Identification in the Persimmon

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THE Oriental persimmon *(Diospyros kaki)* has been grown in California for more than 75 years. Much, if not most, of the nursery stock for the early plantings was imported directly from Japan as varieties propagated on *D. kaki* rootstock. The federal plant quarantine of 1919 prohibited further importations from Japan so California nurserymen turned to local sources of seed for rootstock purposes. Thus *D. lotus* and to some extent *D. virginiana,* came into general use some three decades ago, primarily because these species bear seedy fruit and were already growing in California. *D. kaki* was little employed, presumably because seedy varieties of this species were not generally available. The three species, *D. kaki, D. lotus,* and *D. virginiana,* therefore, are found commonly as rootstocks under older trees in California (2,3) whereas in Florida (1) virtually the only rootstock used is *D. virginiana.*

The marked differences in behavior of some of the principal horticultural varieties of *Diospyros kaki* when grown on the three Diospyros species as rootstock already have been noted (2,4). A knowledge of the identity of the rootstock is therefore important to an understanding of the behavior of certain varieties as it relates to such problems as excessive fruit drop, decline, or other manifestations of incompatibility.

There are several possible means of rootstock identification, namely the use of (a) leaf and bud characters, (b) trunk or bark and bud-union characters, and (c) color reactions of the root-bark extract.

If rootstock sprouts are available or can be induced to develop their identity can easily be verified by the shape, size, color, and pubescence of the buds. Resting buds near the tips of young shoots of *Diospyros kaki* are plump, rounded at the tip, brown colored and generally pubescent. Comparable buds of *D. lotus* are rather flat, acutely pointed, very long, dark colored and generally glabrous. Buds of *D. virginiana* on the other hand, are flat, more or less triangular in form, dark colored and covered with a light bloom. The young shoots of *D. kaki* and *D. virginiana* are variable in respect to the amount of pubescence present. *D. lotus* shoots, on the contrary, are quite glabrous and have many conspicuous lenticels. *D. virginiana* is noted for the excessive numbers of root suckers which develop following root injury, while *D. lotus* and *D. kaki,* generally do not sucker freely.

Bark characters of the three species can, of course, be utilized only if the tree has been budded or grafted at some distance above the soil line or in some instances if the larger roots can be uncovered. Typical barks of the three species may be identified as follows. *Diospyros lotus* has a rather fine textured or smooth bark especially along the older roots below the soil line. Above the soil small, shallow fissures may develop. The bark color is dark especially below the soil, but may become an ashen-gray above ground. *D. virginiana* bark is somewhat rougher with moderately deep and somewhat irregular cracks and is

of lighter color. The bark of *D. kaki*, however, is of a dark reddish color below the soil and of a grayish brown when exposed above the soil. It is also very rough and irregular, the fissures being quite deep.

The line of bud-union of most varieties of *Diospyros kaki* when grown on *D. lotus* root is well marked by an abrupt change in bark texture and color, the rootstock bark being smoother and darker than the scion bark. These differences are not so well marked and are frequently absent when *D. kaki* is used as the stock. Sometimes in the latter case the only indication of a union is an over or undergrowth of the scion, a condition which varies with the scion variety used. *D. virginiana* is quite similar to *D. kaki* in bud-union character.

A third method developed by Terami (5) has proved useful for identification of *Diospyros* species. This method depends upon a color reaction of root bark samples extracted with water. Small fresh samples of bark are cut from the trunk or large older roots well below the soil line. These are weighed, cut into fine pieces and soaked in about 15 times their weight of distilled water in a test tube. After standing from one to several hours the liquid becomes an amber color if the bark is *kaki*, yellow if the bark is *lotus*, and very light yellow or colorless if it is *virginiana*. The liquid can then be decanted off and to it added a few drops of dilute NaOH to make the solution alkaline. The extract of *Diospyros kaki* immediately becomes wine red, that of *D. lotus* turns light amber, and *D. virginiana* becomes light yellow or remains colorless. The present investigation shows that this test identifies *kaki* bark extract with certainty, but occasional variation in color reaction may be found in both *lotus* and *virginiana* bark extracts. Hence the color reaction should be supplemented with morphological verification in the identification of the latter two species.

Root bark extracts determined by the above method have proved useful in the present study for checking the identity of persimmon trees planted on the three common rootstocks. The color reaction was used in testing the rootstock species of 118 trees, the identity of which were known or could be verified by vegetative or trunk-bark characters. These trees are included in a collection of 31 named horticultural varieties and 62 numbered introductions probably the largest of its kind in the United States which has been assembled by Hodgson (2) for horticultural studies on this fruit. Fresh bark samples were used in these tests. Slight drying of the bark samples does not seem to greatly modify the color reaction. The tolerance to drying, seasonal condition of bark and other factors which probably affect the test have not been determined completely. Bark samples taken from above the soil line, however, do not give uniform results.

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Comparative Value of Thirteen Rootstocks for Ten Vinifera Grape Varieties in the Napa Valley in California

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Fruit production and vigor of vinifera grapes varieties growing on their own roots are often decreased by root injury caused by the grape phylloxera (*Phylloxera vitifoliae* (Fitch)). Resistant rootstocks have been used to control this pest. Certain rootstocks have been known to give more satisfactory results than others (2). To obtain additional information on the comparative value of rootstocks, a test plot consisting of 13 selected rootstocks grafted with 10 vinifera grape varieties was started at the United States Experiment Vineyard, Oakville, California, in the spring of 1933.

The Oakville Station is located in the lower portion of the Napa Valley, 161 feet above sea level. The average preciptation from 1915 to 1930 was 31.25 inches (2). Irrigation has never been practiced on this plot. The mean annual temperature is 56.7 degrees F. July has a mean temperature of 66.8 degrees with an absolute maximum of 110 degrees and January has a mean of 46.8 degrees with an absolute minimum of 22 degrees (1).

The soil of the United States Experiment Vineyard at Oakville, ranges from Esparto clay loam to Yolo clay loam (1), with most of the reported test plot classed as Esparto clay loam. Both soil types are easily worked under a wide range of moisture conditions, are well drained, of high water-holding capacity, and permeable to a depth below 6 feet. The clay and silt in the subsoil aid in the retention of moisture although 20 to 40 per cent of gravel is contained in the subsoil. For agricultural value, Esparto clay loam rates 81 and Yolo clay loam 85 out of a possible 100. No alkali is found.

The cultural practices in this test plot consisted of plowing, discing, and cultivating in spring and early summer. No fertilizer was applied or cover-crop grown other than a heavy growth of winter weeds such as mustard, alfilaria, and wild oats.

The soil is infested with grape phylloxera but nematode (*Heterodera maroni* (Cornu) Goody) has never been a problem. Dusting sulphur was used to control powdery mildew (*Uncinula necator* (Schw.) Burr.)

The rootstock vines, 1-year-old, were planted 8 feet apart in rows 10 feet apart. The plot consisted of two blocks (C and D) of 17 rows of 52 vines each. The two blocks were separated by an avenue and the rows of vines on each side of each block and those at each end were considered buffer vines. The rootstocks in the side buffer rows were grafted to the various vinifera varieties but those at the ends were left ungrafted. Of the four side buffer rows, C–1 was planted to Dog Ridge rootstock and D–1 to Solonis x Othello No. 1613, both rootstocks that were being used in the regular test; while C–17 and D–17 were planted to additional rootstocks or rootstocks not planted in the regular test,

Cordifolia x Riparia No. 125–1 and Monticola x Rupestris. Each third row in each block was planted with the rootstock Solonis x Othello No. 1613 to be used as a standard of comparison. The rootstocks were selected from many which in previous tests (2) grew well under various soil and climatic conditions and had sufficient resistance to phylloxera.

The rootstocks were bud-grafted (4) with 10 varieties in the fall of 1934 so that for each variety there were two replications of five vines on each of the 10 rootstocks and 10 replications of five vines on the one rootstock, Solonis x Othello No. 1613. Each buffer row furnished five additional vines of each vinifera variety. The varieties selected consisted of five white wine grape varieties — Semillon, Sauvignon Vert, Chasselas Dore, Gewurz Traminer, Sylvaner; and five red wine grape varieties — Petit Syrah, Zinfandel, Carignane, Mondeuse, and Cabernet Sauvignon. These varieties vary greatly in vigor of vine as is indicated by the weights of wood production in Table I.

A graft-stand of 95 per cent was obtained. Due to uncontrollable circumstances, especially during the early years of growth, the stand of vinifera vines dropped to 68.5 per cent by 1943; but the stand was still 68.1 per cent in 1947, and over 90 per cent of the original rootstocks were growing. The loss in stand was not on any one rootstock.

As the vines were observed from year to year and as growth ratings were obtained, it was evident that Solonis x Othello No. 1613 was not repeating the superior performances reported in the San Joaquin Valley (2), where temperatures are higher and irrigation is practiced. There was a considerable range in the growth ratings of the rootstocks. Solonis x Othello No. 1613 ranked among the weaker rootstocks and Rupestris St. George (the rootstock most used in commercial vineyards in the Napa Valley at present) ranked among the stronger rootstocks. In order to present a better comparison of the stronger rootstocks, Rupestris St. George is used as the standard of comparison rather than Solonis x Othello No. 1613 as originally planned.

To aid in the evaluation of the rootstocks, fruit production weights, pruning wood weights, and vine growth ratings were obtained for a 2-year period, 1946 and 1947. All vines were given growth ratings by one individual, scores of 1 to 10 being used where 1 indicated very weak growth and 10 indicated very strong healthy growth for the variety. Table I contains the averages for the 2 years of fruit weights, wood weights, and growth ratings of ten varieties on Rupestris St. George, the standard of comparison. The actual differences, plus or minus, from the standard are given for the varieties on the other 12 rootstocks, with one asterisk following if the difference is significant and two asterisks if highly significant. The fruiting varieties are tabulated and discussed in order of their location in block C of the test planting.

Semillon:—The fruit production in pounds per vine ranged for the various rootstocks from 8.3 to 15.7, or at the rate of 2.25 to 4.26 tons per acre. The pruning wood weights for this rather medium to weak growing variety ranged from 1.1 to 3.7 pounds per vine. Mourvedre

x Rupestris No. 1202, Solonis x Othello No. 1613, and Monticola x Riparia No. 18815 were the three lowest ranking rootstocks. Among the other 10, there were no significant differences although Rupestris St. George was generally a little superior.

Sauvignon Vert:—The fruit production in pounds per vine ranged from 10.0 to 27.9, or at the rate of 2.72 to 7.57 tons per acre. The pruning wood weights ranged from 1.3 to 6.9 pounds per vine. Rupestris St. George rates highest. Rating next are Dog Ridge, Constantia, Mourvedre x Rupestris No. 1202, and Cordifolia x Riparia No. 125–1 (buffer row).

Gewurz Traminer:—The fruit production in pounds per vine ranged from 5.1 to 12.9, or at the rate of 1.39 to 3.51 tons per acre. The pruning wood weights ranged from 1.1 to 3.7 pounds per vine, indicative of the relatively medium weak vine growth of this variety. Rupestris St. George, Dog Ridge, Constantia, Mourvedre x Rupestris No. 1202, and Monticola x Rupestris (buffer row) are the five rootstocks rating highest and there are no significant differences among them; however, the trend favors Rupestris St. George, Constantia, and Monticola x Rupestris (buffer row).

Chasselas Dore:—The fruit production in pounds per vine ranged from 2.9 to 16.6, or at the rate of .79 to 4.50 tons per acre. The pruning wood weights ranged from 1.2 to 6.3 pounds per vine. Rupestris St. George, Mourvedre x Rupestris No. 1202, and Monticola x Rupestris (buffer row) are the three rootstocks with highest ratings, there being no significant differences between them.

Sylvaner—The fruit production in pounds per vine ranged from 9.0 to 17.7, or at the rate of 2.44 to 4.80 tons per acre. The pruning wood weights ranged from 1.8 to 9.3 pounds per vine. Rupestris St. George, Dog Ridge, Constantia, Mourvedre x Rupestris No. 1202, Monticola x Rupestris (buffer row), Riparia x Rupestris No. 3309, Berlandieri x Riparia No. 420–A and Cordifolia x Riparia No. 125–1 (buffer row) were the eight rootstocks rating highest with no significant differences among them.

Petit Syrah:—The fruit production in pounds per vine ranged from 6.2 to 17.7, or at the rate of 1.68 to 4.80 tons per acre. The pruning wood weights of this medium weak growing variety ranged from .7 to 3.7 pounds per vine. Rupestris St. George and Mourvedre x Rupestris No. 1202 were the two rootstocks rating highest, with the trend favoring Rupestris St. George. Dog Ridge and Constantia were next in rank.

Zinfandel:—The fruit production in pounds per vine ranged from 6.0 to 18.8, or at the rate of 1.63 to 5.10 tons per acre. The pruning wood weights ranged from .7 to 7.9 pounds per vine. Rupestris St. George rates highest with Mourvedre x Rupestris No. 1202, Dog Ridge, Constantia, and Monticola x Rupestris (buffer row) rating next.

Carignane:—The fruit production in pounds per vine ranged from 9.5 to 26.5, or at the rate of 2.58 to 7.20 tons per acre. The pruning wood weights ranged from .9 to 6.3 pounds per vine. Rupestris St.

TABLE I—Fruit Production (a) and Wood Production (b) in Pounds Per Vine and Growth Ratings (c) of Ten Vinifera Varieties Grafted on Rupestris St. George, the Standard of Comparison. The Respective Differences from the Standard are Listed for the Ten Vinifera Varieties Growing on Twelve Comparative Rootstocks. (Averages for 1946 and 1947, the 12th and 13th Years in the Life of the Vines)

Rootstocks		Vinifera Varieties									
		Semillon	Sauvignon Vert	Gewurz Traminer	Chasselas Dore	Sylvaner	Petit Syrah	Zinfandel	Carignane	Mondeuse	Cabernet Sauvignon
Rupestris St. George	(A)	12.4	27.9	9.0	11.1	10.5	17.7	18.8	26.5	14.2	16.2
(Standard of Comparison)	(B)	3.3	6.9	2.9	6.3	9.3	3.7	7.9	6.3	4.8	9.7
	(C)	9.3	8.9	9.4	9.7	9.8	9.5	9.7	9.8	9.4	9.8
Dog Ridge		- 2.3	- 6.3*	+ 2.8	- 1.8	+ 7.2	- 1.7	- 1.9	- 2.3	+ 1.1	+ 0.6
		+ 0.3	- 2.4*	- 0.4	- 4.2*	- 3.3	- 1.6*	- 2.3**	- 2.5*	+ 1.2	+ 0.9
		- 0.3	+ 0.7	- 0.1	- 1.6**	- 0.1	- 0.4	- 0.5	- 0.6*	+ 0.3	+ 0.3
Salt Creek		- 1.1	- 12.3*	- 3.4**	- 6.6*	+ 1.5	- 10.0**	—	- 10.8	- 6.0	- 2.8
		- 0.4	- 5.0**	- 1.2	- 5.6**	- 6.9**	- 2.8**	—	- 4.1**	- 2.8**	- 5.1**
		- 0.9	- 1.0*	- 1.5*	- 4.0**	- 2.3*	- 4.7**	—	- 1.1	- 1.2	- 1.0*
Chasselas × Berlandieri No. 41-B		- 2.4	- 13.2**	- 2.1	- 3.0	+ 1.4	- 10.4**	- 11.8**	- 12.5*	- 6.6	- 2.4
		- 1.5	- 4.9**	- 1.2*	- 4.4*	- 7.0*	- 2.1**	- 3.7**	- 4.5**	- 2.7*	- 5.2**
		- 1.3	- 0.8	- 2.1**	- 2.4**	- 2.5**	- 2.2**	- 3.0**	- 2.0**	- 2.3	- 0.5
Berlandieri × Riparia No. 420-A		- 4.1	- 17.8**	- 0.7	- 8.2**	- 0.3	- 10.5**	- 7.9**	- 13.4*	- 5.7*	- 5.8
		- 0.9	- 5.4**	- 0.6	- 4.1*	- 4.3	- 3.0**	- 4.2	- 5.1**	- 2.8**	- 6.0**
		- 0.3	- 1.7*	- 1.2	- 4.2**	- 1.3	- 2.9*	- 7.9**	- 3.1*	- 1.4	- 1.5
Mourvedre × Rupestris No. 1202		- 3.6	- 10.4*	- 0.1	+ 0.7	+ 3.6	- 4.4	- 2.7	- 6.7	- 0.9	- 2.0
		- 2.2**	- 2.6*	+ 0.1	- 2.0	- 3.6	- 1.0	- 2.1*	- 2.8*	+ 1.3	- 3.9**
		- 2.8**	+ 0.5	- 1.4	- 0.5	- 0.4	- 0.3	- 0.4	- 0.3	- 1.8	+ 0.1
Monticola × Riparia No. 18815		+ 0.1	- 14.1**	- 1.1	- 2.5	+ 1.9	- 11.5**	- 12.5**	- 10.6	- 6.0	- 5.0
		- 1.5*	- 5.1**	- 1.1	- 5.1**	- 6.6**	- 2.8**	- 4.0**	- 4.3**	- 3.0**	- 5.3**
		- 1.1	- 1.0*	- 1.0**	- 2.9**	- 1.6*	- 2.6*	- 3.4**	- 1.2*	- 2.0	- 1.3*

Riparia × Rupestris No. 101-14	− 1.8	− 10.5**	− 3.9*	− 6.0**	+ 2.8	− 5.6**	− 11.6**	− 9.1	− 2.3	− 4.3
	− 0.9	− 3.8**	− 1.5*	− 4.9**	− 4.9	− 2.1**	− 3.9**	− 3.7**	− 0.7	− 5.9**
	− 0.8	− 0.1	− 2.2*	− 2.5**	− 2.9**	− 1.1*	− 3.1**	− 0.9**	− 2.0	− 2.2
Riparia × Rupestris No. 3309	− 1.0	− 11.5**	+ 0.5	− 1.0	− 3.6	− 11.4**	− 12.7**	− 13.8*	− 2.0	− 4.0
	− 1.2	− 3.8**	− 1.1	− 4.5*	− 5.4*	− 2.8**	− 4.0**	− 4.8**	− 1.0	− 6.2**
	− 1.3	− 0.1	− 1.2*	− 2.2**	− 0.8	− 3.5*	− 4.4**	− 2.2**	− 0.3	− 0.5
Solonis × Othello No. 1613	− 3.5	− 16.9**	− 1.4	− 7.7**	− 1.5	− 11.1**	− 9.9**	− 16.6**	− 5.0	− 5.4
	− 1.5*	− 5.5**	− 1.5	− 5.8**	− 7.5**	− 3.0**	− 3.8**	− 5.4**	− 2.9**	− 6.6**
	− 1.5**	− 1.5**	− 1.8**	− 5.1**	− 3.5**	− 3.3**	− 3.5**	− 3.5**	− 1.8**	− 2.3**
Constantia	+ 1.6	− 7.4*	+ 3.9	+ 2.2	+ 4.5	− 3.5	− 6.6	− 14.5*	− 1.1	− 1.3
	− 0.1	− 2.1*	+ 0.0	− 3.8*	− 3.4	− 1.9*	− 3.2	− 4.4**	− 0.9	− 3.3**
	− 0.6	+ 0.8	− 0.2	− 1.3	− 0.2	− 0.5	− 1.7	− 1.9*	+ 0.1	+ 0.1
Cordifolia × Riparia No. 125-1 (buffer row)	+ 3.3	− 7.8	− 3.1	——	+ 3.0	——	——	——	+ 0.2	+ 0.3
	− 0.7	− 3.9**	− 1.8*	——	− 6.4*	——	——	——	− 1.8	− 5.1**
	− 0.1	+ 0.1	− 1.9	——	− 2.0	——	——	——	− 1.1	− 0.2
Monticola × Rupestris (buffer row)	− 1.0	− 14.4**	+ 6.0	+ 5.5	+ 1.2	− 10.4**	− 9.6	− 12.6	+ 0.2	− 1.5
	− 0.1	− 3.4**	+ 0.8	− 0.7	− 0.9	− 2.7**	− 3.5	− 3.8	− 1.2	− 4.1**
	+ 0.1	− 0.3	− 0.6	− 0.1	− 0.7	− 1.5**	− 1.4	− 2.7	00.0	− 0.1

*Significant difference, or 95 per cent probability.
**Highly significant difference, or 99 per cent probability.

George rates highest. Dog Ridge, Mourvedre x Rupestris No. 1202, and Monticola x Rupestris (buffer row) rate next.

Mondeuse:—The fruit production in pounds per vine ranged from 7.6 to 16.3, or at the rate of 2.06 to 4.44 tons per acre. The pruning wood weights ranged from 1.8 to 6.0 pounds per vine. Rupestris St. George, Dog Ridge, Constantia, Mourvedre x Rupestris No. 1202, Monticola x Rupestris (buffer row), Riparia x Rupestris No. 3309, Riparia x Rupestris No. 101–14, and Cordifolia x Riparia No. 125–1 (buffer row) are the eight rootstocks rating highest and showing no significant differences. The trend favors Dog Ridge.

Cabernet Sauvignon:—The fruit production in pounds per vine ranged from 10.4 to 16.9, or at the rate of 2.82 to 4.60 tons per acre. The pruning wood weights ranged from 3.1 to 10.9 pounds per vine. Dog Ridge and Rupestris St. George are the two rootstocks rating highest, with Dog Ridge a little ahead in fruit, wood, and growth rating but not to a significant degree.

Summary

This test covered 10 vinifera varieties grafted on 13 rootstocks in the Napa Valley in California. Data on the fruit weights, pruning wood weights, and growth ratings, taken during the 12th and 13th years from budding, indicate a wide range in value of the varied rootstocks tested for this locality. The five highest ranking rootstocks are Rupestris St. George, Dog Ridge, Constantia, Mourvedre x Rupestris No. 1202, and Monticola x Rupestris. Of these five, Rupestris St. George, the rootstock most widely used commercially in this district, was equal to the best of the other rootstocks or was slightly superior in most of the tests.

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Relation of Wax Emulsion and Fungicidal Sprays to Size, Color, and Composition of Fresh and Processed Montmorency Cherries[1]

By C. A. LANGER and VERNON J. FISHER, *Michigan State College, East Lansing, Mich.*

A WAX emulsion applied to Montmorency cherry trees in combination with the usual fungicidal mixtures, has resulted in an increase in size of fruit of about 10 per cent over trees receiving the same fungicidal spray treatment without the emulsion (1, 2, 3). During the season of 1947 cherry canners reported instances of inferior quality of processed cherries, possibly associated with field application of this emulsion. The effects reported consisted of pale color, insipid taste, soft fruit which did not become firm after cooling in water bath, injury to fruit in pitting, and adherence of spray residue to fruit.

Experiments were conducted in 1948 to determine the effect of two different fungicidal sprays, alone and in combination with wax emulsion, on size and quality of red cherries. Additional data were obtained regarding the effect on size. The experiments were also designed to show the relative effects on size and quality of the two fungicidal programs without the use of the emulsion. All studies were conducted at two levels of nitrogen fertility. Since no difference could be detected between the different rates of fertility this factor was disregarded in the analysis of data.

MATERIALS

The wax emulsion used was Dowax 222, a commercial product manufactured by the Dow Chemical Company, Midland, Michigan. This was the same material used by Neal *et al.* and Langer. The fungicides used were Bordow, a proprietary copper material manufactured by the Dow Chemical Company, and fermate (ferric dimethyldithiocarbamate), an organic fungicide manufactured by E. I. du Pont de Nemours Company, Wilmington, Delaware.

METHODS OF INVESTIGATION

Field Trials:—The field trials were conducted in three privately owned cherry orchards, located at Fennville, Gobles, and Traverse City, Michigan, and designated as orchards I, II, and III respectively.

Orchard I comprised a single block of trees all of which received fungicidal sprays of Bordow, while orchards II and III were each divided into a Bordow block and a Fermate block. Each block of all

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orchards contained three plots of two or three rows, the rows containing from 20 to 30 trees each.

Plot 1 of each block received no Dowax, plot 2 received one application of Dowax, and plot 3 received two applications. Dowax was used at a concentration of 1 per cent by volume. Where one application of Dowax was made it was included with the second cover spray, at the time the cherry pits had reached full size and the fruit had begun to color. Where two applications were made Dowax was included with the second and third cover sprays, the third being applied 7 to 10 days after the second, or when fruit showed about 25 per cent red color.

One end of each block in orchards II and III received a high rate of nitrogen fertilization (10 and 8 pounds ammonium nitrate respectively), while the other end received a medium rate (6 and 5 pounds, respectively). Orchard I was fertilized uniformly throughout at 2 pounds ammonium sulphate per tree.

Cultural Practices:—Trees of orchard I were on Mahaleb roots, and were spaced 20 feet apart on the square. The trees were larger than in the other two orchards. The orchard was 16 years old. It was managed under a system of clean cultivation and cover crop. A sudan grass cover was grown the previous fall. The set of fruit in 1948 was 75 per cent due to inadequate pollination resulting from rain and cool weather during blossoming. The orchard received three cover sprays after blooming.

Trees of orchard II were on Mazzard roots, and were spaced 15 feet apart on the triangle. The orchard was 39 years old and was managed under a system of clean cultivation and cover crop. A rye grass cover crop was grown in the orchard during the previous fall. The cover crop received 200 pounds of an 0-20-20 fertilizer per acre. The set of fruit was about 90 per cent. The orchard received four cover sprays after blooming.

Trees of orchard III were on Mahaleb roots and were spaced 18 by 20 feet. The orchard was 21 years old and was managed under a system of clean cultivation and cover crop. The cover crop during the previous season was Chewings fescue. The set of fruit was about 90 per cent. The orchard received four cover sprays after blooming.

The trees of all three orchards were large and vigorous. Excellent insect and disease control was secured in all orchards. The growing season was better than average for all three locations. The soil in all three orchards was sandy loam underlain by a clay layer at 3½ to 4 feet below the surface.

Cover sprays were mixed as follows, except for the inclusion of Dowax as described above: Bordow was mixed at the rate of 4 pounds Bordow, 3 pounds lime, and 2 pounds lead arsenate per 100 gallons of material; Fermate was mixed at the rate of 2 pounds of Fermate and 2 pounds of lead arsenate per 100 gallons of material.

Processing Practices:—The facilities of three large commercial processing plants were used in processing the cherries. The fruit was moved to the plants in lugs, and conveyed by automatic elevators to large metal tanks filled with cool running water (54 degrees F). After 12 to 18 hours in these cooling tanks the cherries were passed over

grading belts where foreign matter and defective fruits were removed, and thence to the pitters and can fillers by endless belts. The cans of fruit were then filled with hot water, capped, cooked, cooled, and packaged, except for a small number of cans which were, "removed at random, for special purposes, as they left the fillers." Sixteen No. 2 cans were canned in light sirup and 10 were frozen. In cases where no No. 10 can line was operating additional No. 2 cans were emptied into No. 10 cans for drained weight determinations.

Size Determination:—The effect of the emulsion and of the two fungicides on size was determined for three to five trees from each plot that were relatively uniform in size, vigor, and freedom from observable winter injury and virus infection. Three samples of 100 cherries each were picked from each tree. These samples were picked from spurs only, taking the entire spur cluster, at random from the entire tree so as to secure a fair representation of the total crop. The samples were weighed, and volume was then determined by water displacement in a 500 ml graduated cylinder.

Composition and Quality Determinations:—Soluble solids were determined by the refractometer method, and expressed as sucrose. Each treatment was sampled by picking two to four cherries from spurs at random throughout the entire plot. These samples were taken to the processing plants involved where plant chemists made the readings. The readings were repeated until at least three closely agreeing values were obtained for each treatment.

Total solids were determined by drying a composite sample of from 100 to 200 grams in an oven at 100 to 105 degrees C for 24 hours.

The uptake of water by cherries in the cooling tanks prior to pitting was determined by placing a 50-pound sample in a wire mesh basket (2 feet in diameter and 2 feet deep) and suspending in the cooling tank. The sample was weighed before and after cooling. In order to obtain weights at the beginning of the cooling period under conditions comparable to those at the close of the period, the sample was first suspended in the tank until thoroughly wetted and then drained for 5 minutes before weighing. The same draining period was allowed after cooling.

Drained weights were determined on No. 10 cans, the put-in weight for which was known. The standard drained weight test was used, made by emptying the contents of one can onto a screen strainer, allowing to drain in an inclined position for 2 minutes, and weighing the drained fruit.

The adherence of spray material to fruit was determined by visual observation, and by residue tests for arsenic and lead on water packed fruit a month after canning. These tests were made by chemists of the Michigan Department of Health.

Quality of processed fruit was determined by a panel of judges consisting of qualified commercial processors and college faculty. Fruit was judged on the basis of color (20 points), general appearance (20 points), texture (20 points), and flavor (40 points). The judging was done 2 to 4 weeks after processing and again 2 months after processing.

Results and Discussion

Data on the size of cherry fruit from trees receiving fungicidal sprays of Bordow and Fermate, alone and in combination with Dowax 222 are presented in Table I. There was an increase in the size of fruit from trees which received Fermate in comparison with trees receiving Bordow, confirming observations made in 1947. There also was an increase in size of fruit from trees which received Dowax 222 in combination with fungicidal sprays over those which received no Dowax. The relative increases were similar to those observed in 1947 (1) and 1948 (2).

Table I may be summarized as follows:

Average increase from use of Fermate over Bordow = 9.8 per cent

Average increase from one application of Dowax with Bordow = 10.8 per cent

Average increase from one application of Dowax with Fermate = 5.8 per cent

Average increase from two applications of Dowax with Bordow = 13.9 per cent

Average increase from two applications of Dowax with Fermate = 10.7 per cent

Table I gives data on size expressed only in terms of weight. The

TABLE I—Effect of Fermate and Bordow Alone and in Combination With Dowax 222 on Size of Montmorency Cherries

Plot No.	Dowax Treatment	Average Circumference of Trunk (Inches)	Average Yield Per Tree (Pounds)	Average Weight 300 Cherries (Grams)	Increase From Dowax* (Per Cent)	Increase From Fermate** (Per Cent)	Increase From Dowax and Fermate† (Per Cent
			Orchard I				
1 Bordow	None	32.3	169	1,258	—	—	—
2 Bordow	Second cover	32.5	203	1,401	11.4	—	—
3 Bordow	Second and third cover	29.5	204	1,366	8.7	—	—
			Orchard II				
1 Bordow	None	26.7	136	1,296	—	—	—
1 Fermate	None	25.4	121	1,425	—	7.0	7.0
2 Bordow	Second cover	25.0	131	1,475	13.8	—	—
2 Fermate	Second cover	26.3	134	1,477	3.7	0.1	14.0
3 Bordow	Second and third cover	25.8	123	1,489	15.6	—	—
3 Fermate	Second and third cover	28.0	121	1,622	13.8	8.9	25.2
			Orchard III				
1 Bordow	None	25.0	220	1,147	—	—	—
1 Fermate	None	24.9	242	1,343	—	17.1	17 1
2 Bordow	Second cover	26.4	308	1,230	7.2	—	—
2 Fermate	Second cover	28.5	252	1,451	8.0	18.0	26.5
3 Bordow	Second and third cover	26.6	260	1.346	17.3	—	—
3 Fermate	Second and third cover	24.7	253	1,445	7.6	7.4	25.8

*Increase over same fungicide without Dowax.
**Increase of Fermate plots over Bordow plots receiving similar Dowax treatment.
†Combined effect of Dowax and Fermate, as compared to Bordow with no Dowax treatment.

correlation between weight and volume was so close that publication of volume data would be an unnecessary duplication.

While the magnitude of increase from both variables was not consistent, there is little reason to doubt that the increases were real and appreciable. Variations in pounds per tree was due to trees varying in bearing surface. Variations in size were brought about by variable vigor of trees; by lack of uniformity in sampling; by variations in productivity of the soil; and by differences in the stage of maturity at the time of sampling. These factors were kept to a minimum, but they were sufficient to make it difficult to predict what can reasonably be expected under different conditions.

Table II shows the soluble solids and total solids content of fruit from the different treatments.

Results in orchard I were too variable to have value. It will be remembered that this orchard had a 75 per cent set of fruit, that the trees were larger, more vigorous, and more widely spaced than those of the other orchards, and that the amount of nitrogen fertilizer used was relatively low. Under these conditions nitrogen supply very likely determined size and composition to a large extent, and local soil variations accounted for the large amount of variation in solids content.

An inspection of Table II reveals a definite decrease in soluble solids and total solids on the percentage basis, both from the use of Dowax 222 with fungicides, and from the use of Fermate as compared to Bordow as the fungicide. However, the actual amount of solids in a given number of cherries did not increase. In fact a slight decrease was indicated from the use of Dowax 222, although this point has not been

TABLE II—Solid Content of Fresh Cherries From Trees Which Received Fungicidal Sprays of Bordow or Fermate, Alone and in Combination With Dowax 222

Plot No.	Dowax Treatment	Bordow Blocks			Fermate Blocks		
		Soluble Solids* (Per Cent)	Total Solids		Soluble Solids* (Per Cent)	Total Solids	
			Per Cent	Grams (300 Cherries)		Per Cent	Grams (300 Cherries)
			Orchard I				
1	None	13.9	—	—	—	—	—
2	Second cover	11.3	—	—	—	—	—
3	Second and third cover	13.9	—	—	—	—	—
			Orchard II				
1	None	14.5	15.0	194	12.3	14.0	200
2	Second cover	13.7	13.7	202	11.0	12.3	182
3	Second and third cover	12.0	11.5	171	11.3	11.5	177
			Orchard III				
1	None	13.7	16.9	194	11.6	13.8	185
2	Second cover	12.0	15.4	189	10.6	12.1	176
3	Second and third cover	11.7	13.8	186	10.4	12.1	175

*Expressed as sucrose.

definitely established by the data presented. The authors feel that some physiological response must have taken place, resulting in a lower solids content per individual cherry fruit. No conclusion can be drawn at this time concerning the physiological effects of Fermate as compared to Bordow, although further work may shed some light upon this question.

No trend was established in the uptake of water by cherries in the cooling tanks. In fact no sample increased in weight enough to consider the uptake of water beyond the probable limits of error.

Table III shows drained weights of No. 10 cans of cherries from the various treatments. The put-in weight in most cases was 85 ounces per can. Whenever a different put-in weight was used the actual drained weight was adjusted accordingly, and expressed on the basis of an 85-ounce filling.

TABLE III—Drained Weight of Canned Cherries From Trees Which Received Fungicidal Sprays of Bordow or Fermate Alone and in Combination With Dowax 222

No.	Dowax Treatment	Bordow Blocks Drained Weight Per No. 10 Can (Ozs)	Fermate Blocks Drained Weight Per No. 10 Can (Ozs)
	Orchard I		
1	None	74.7	—
2	Second cover	72.2	—
3	Second and third cover	68.6	—
	Orchard II		
1	None	75.0	73.5
2	Second cover	69.3	68.0
3	Second and third cover	68.1	66.8
	Orchard III		
1	None	75.1	72.8
2	Second cover	72.7	71.6
3	Third cover	72.0	71.5

Without exception, the drained weight of cherries from trees receiving fungicidal sprays of Fermate was lower than from trees receiving Bordow, other conditions being the same. Also drained weights were lower when Dowax was included with the spray mixture than where it was not. The decrease was greater where two Dowax sprays were used than where only one was used.

It is assumed that this decrease in drained weight of canned cherries was a function of the greater water content of the fresh fruit. The larger cherries contained more water and lower percentage of sugar than the smaller ones. The larger cherries bruised more readily and more cells were ruptured in handling, and consequently lost more into the water which was added in canning. The fruit containing the higher concentration of sugar was smaller, more firm and consequently fewer ruptured cells and torn cherries occurred in processing. Non-ruptured cells after processing are still able to hold large molecules, such as sugar, from passing through the membrane.

A drained weight of 74 ounces per No. 10 can is required for cherries to be classified as U. S. No. 1 Grade. This necessitates a higher put-in weight for Fermate and/or Dowax treated cherries.

Before the cherries were picked it was observed that a spot of spray material had collected on the lowermost part of practically every cherry. This spot was easily removed on all plots except where Dowax was used in conjunction with Fermate. After the fruit had gone through the cooling tanks this residue was gone from all the fruit except those from plot No. 6, which had received two sprays of Dowax in conjunction with Fermate. About half the cherries from this plot carried residue spots into the cans. This residue gradually dissolved, until after 2 months only an occasional fruit was found to be spotted.

The results of laboratory tests for lead and arsenic on canned fruit from orchard II are shown in Table IV. Much higher residue was found on samples from the plot which had received two sprays of Dowax with Fermate, although appreciable quantities of residue, especially lead, were found in other samples. The tolerance for fresh fruit is given in Table IV purely for illustrative purposes. No tolerances have been established for canned cherries.

The averages of all judges scores for quality of processed fruit were as follows:

Fungicide	Dowax treatment	Score (possible 100)
Bordow	None	62
Bordow	Second cover	62
Bordow	Second and third cover	55
Fermate	None	54
Fermate	Second cover	49
Fermate	Second and Third cover	45

Cherries from plots which had received Dowax in conjunction with Fermate were considered inferior to the others by all judges. The other plots gave very little differences in quality. The chief causes of low scores were pale color and somewhat insipid taste. The same trend in quality was noted regardless of the method of processing, although some judges preferred the pale red color of the Fermate and Dowax treated cherries to the brownish red color of the fruit from the other plots.

TABLE IV—ARSENIC AND LEAD TESTS ON CANNED CHERRIES FROM ORCHARD II

Fungicide	Dowax Treatment	Arsenic (as As_2O_3) Gr/Lb	Lead Gr/Lb
Bordow	None	Trace	0.024
Bordow	Second cover	Trace	0 014
Bordow	Second and third cover	0.003	0.017
Fermate	None	0.006	0.026
Fermate	Second cover	0.005	0.005
Fermate	Second and third cover	0.018	0.040
U.S.D.A. tolerance for most fresh fruit		0.025	0.050

Summary

The use of Dowax 222 in three Michigan orchards in 1948, applied as a spray to the fruit and foliage during the growing season increased the size of Montmorency cherries over those which received no Dowax. Increases were obtained when the emulsion was incorporated with either Bordow or Fermate. Cherries receiving Fermate as the fungicide with or without Dowax were larger than those receiving Bordow with similar Dowax application.

The use of Dowax 222 lowered the soluble solids and total solids content of fresh cherries and the drained weight of canned cherries in comparison with similar cherries which received no Dowax.

Adherence of spray residue to fruit was quite serious where Dowax 222 was used in conjunction with Fermate in two applications.

No appreciable amount of water was taken up by cherries in the cooling tanks regardless of spray treatment.

A panel of judges considered the processed fruit from plots which received Bordow as the fungicide to be of slightly higher quality than those which had received Fermate. The use of one application of Dowax with Bordow did not impair quality, while the use of Dowax with Fermate resulted in processed fruit of decidedly inferior quality.

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The Effects of Urea and Oil-Wax Emulsion Sprays on the Performance of the Concord Grapevine Under Cultivation and in Ladino Clover Sod[1]

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THE successful use of spray solutions containing micronutrients to correct deficiencies in some fruit plants has led to several attempts to improve vigor and yield by foliage sprays supplying nitrogen in the form of urea. Investigators in New York (1,2) have found that leaf sprays of urea can maintain a McIntosh apple tree in an apparently satisfactory level of nitrogen nutrition. A program in which urea was added to two pre-bloom, a petal fall, and a first cover spray caused a heavier set of fruit and better fruit color than a spring soil application. Midsummer urea sprays tended to increase the size of fruit, but markedly reduced the color. Harley, Moon, and Regeimbal (3) reported significant increases in chlorophyll and nitrogen contents of foliage of the York Imperial apple sprayed with urea solution. Havis and Prince (4) observed no difference in fruit color, time of ripening, or nitrogen content of leaves at four different sampling dates, on 4-year-old peach trees sprayed with urea at concentrations as high as 50 pounds to 100 gallons of water. In California, Williams (12) found no evidence of major element absorption by grape leaves. Mack and Shaulis noted improved leaf color (6) and later shoot growth (7) on Concord grapevines sprayed with urea, but no significant difference in total nitrogen in the leaf blades.

Some sprays devoid of mineral elements have benefited fruit plants. Neal and his co-workers (9) in Michigan were able to increase the size of Montmorency sour cherries by the application of oil-wax emulsion sprays. They found that reduction in the rate of transpiration was the main factor contributing to the production of larger fruit (8). Other work at the same Station by Langer (5) demonstrated increases in fruit size of sour cherries, sweet cherries, and Bartlett pears, but no size increases in Kieffer pears, Delicious or Golden Delicious apples.

The studies described in this paper deal with sprays of urea and of an oil-wax emulsion on Corcord grapevines (*Vitis Labrusca*, L.) over a three-year period.

MATERIALS AND METHODS

The experiments were conducted at North East, Pennsylvania, in a Concord vineyard owned and operated by H. G. Naylor. Vines are set at 8 feet in rows 9 feet apart. They varied in age but most of them were in their eighth year when the sprays were first applied in 1946. Some

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were much older (age unknown) and an occasional replant was younger. Data included in this report are from mature vines only.

The soil is classified as Braceville gravelly sandy loam. Although the topography of the area is rolling, the experimental block is nearly level, sloping very slightly to the south and west. The site is inclined to be frosty. Yields in 1946 and 1948 were reduced by low temperature injury.

In August, 1944, one-half of the 2-acre experimental vineyard was seeded to Ladino clover (*Trifolium repens* L.). Details of the soil management methods followed in the two blocks from this time through 1948 are given in Table I. A dense volunteer stand of domestic ryegrass appeared in the sod block early in the spring of 1945 and apparently deprived the vines of part of their usual nitrogen supply. Poor leaf color associated with nitrogen deficiency was evident in mid-June. Nitrate of soda was applied at 0.6 pound per vine in a 4-inch band alongside the row, approximately 2 feet from the vines, on June 26. Recovery in leaf color was complete within a week following a rain. After several mowings the Ladino was predominant, and an excellent clover sod covered the block during 1945 and 1946. Non-legumes began to encroach into the Ladino in 1947 and 1948.

It was this experience in 1945 which suggested the possibility of using one or more midsummer urea sprays in place of the midsummer soil application to maintain a satisfactory level of nitrogen nutrition. Although no deficiency was anticipated in the cultivated block it was thought that urea sprays over a period of years at this season might result in improved yield through increased vigor of vine.

Each 1-acre block was divided into 14 0.04-acre plots, providing for five replications of each treatment. The four control plots were located so that each plot receiving treatment was adjacent to a control plot. Records were taken from 14 vines per plot, seven vines in each of the two adjoining center rows in the plot.

Yield records of individual vines were taken by counting the clusters as they were picked from each vine and weighing the total yield from each vine separately. One pint of berries was collected from each plot by picking a single berry at random from individual clusters and sampling from mature vines only. The berries in each sample were counted and weighed, and the average grams per berry determined.

TABLE I—SOIL MANAGEMENT IN THE NAYLOR VINEYARD (1944 TO 1948)

Year	Materials Applied Per Acre	
	Cultivated* and Ladino Clover† Blocks	Ladino Clover Block Only
1944	500 Lbs. 10-5-11‡	2 tons ground limestone in late fall
1945	500 Lbs. 9-6-8	10 tons barnyard manure in early spring
1946	600 Lbs. 9-6-8	1 ton ground limestone in late fall
1947	500 Lbs. 10-6-10	
1948	500 Lbs. 10-6-10	

*Clean cultivation from early spring until early August, when cover crop of domestic ryegrass was seeded; all fertilizer applications were made in the spring.
†Ladino clover was seeded in August, 1944; it was mowed six times in 1946, five times in 1947, and five times in 1948.
‡Fertilizers were special mixtures made to the grower's specifications.

In pruning, only 1-year wood was weighed from each vine. The number of buds to be left for next year's crop was calculated from the pruning weight of the vine on the basis of 30 buds for the first pound of prunings and two buds for each ¼ pound over 1 pound.

A sample of 30 leaves was taken for analysis in 1946 from 18 of the 28 plots. The first fully expanded leaf nearest the end of each of 30 bearing shoots on mature vines were collected as a sample for each plot. These samples were taken on August 13, 26 days after the treatments were applied.

Urea Sprays:—NuGreen, a proprietary form of urea containing 43 per cent nitrogen, was used in these studies. It was supplied by the DuPont Company of Wilmington, Delaware. Tests in June 1946 to determine the proper dilution for use on the Concord grape indicated that 5 pounds of NuGreen to 100 gallons of water was near the maximum which could be used without causing leaf injury. However, 6 and 7 pounds to 100 gallons were used without injury in the midsummer sprays applied in 1948. Apparently the matured leaves can stand a higher concentration that those in an actively growing condition.

Complete coverage and a minimum of drift were assured by the use of a spray rig with a covered boom. All sprays were applied independently of those applied by the grower for the control of insects and diseases. One pint of Orthex spreader was added with NuGreen to each 100 gallons of spray. Dates of application are given in Tables II and III. Clusters were in full bloom on June 26 in each of the three years of the experiment.

In 1946, the NuGreen foliage spray was compared with a soil application. One-third of a gallon per vine of the spray solution (the same amount as each vine received in the spray treatment) was poured on the soil along the row about 2 feet from the base of the vines. This 1946 soil application of urea was replaced by the oil-wax sprays in the same plots in 1947 and 1948.

Oil-wax Emulsion Sprays:—Dowax 222, a commercially prepared oil-wax emulsion, was supplied for these tests by the Dow Chemical Company of Midland, Michigan. It was used on the dates given in Tables II and III at the rate of 1 gallon of the material to 100 gallons of the spray solution.

Results and Discussion

Urea Sprays:—There was no significant effect on yield or vine vigor from the four urea sprays applied during a 3-year period (Tables II and III). Applications of the spray solution to the soil in 1946 also failed to affect the performance of the vine in either the cultivated or the Ladino sod blocks. The lower average number of clusters in the 1946 urea sprayed sod plots (Table II) could have been the result of spring frost injury which was more severe on weaker vines. Vines in all plots exhibited good leaf color during the entire period of the experiment.

The evidence indicates that little, if any, additional nitrogen was taken into the vine from the applications of urea in these tests. When percentages of nitrogen in 1946 leaf samples from treated plots were

TABLE II—EFFECTS OF UREA AND OIL-WAX EMULSION SPRAYS ON VIGOR AND YIELD OF CONCORD GRAPEVINES IN LADINO CLOVER SOD

Treatments and Dates of Application	Vines (Number)	Average Yield		Average Clusters Per Vine (Number)	Average Weight Per Cluster (Pounds)	Average Weight Per Berry (Grams)	Increase in Berry Weight (Per Cent)	Average Weight of Prunings Per Vine (Pounds)
		Weight Per Vine (Pounds)	Weight Per Acre* (Tons)					
			1946					
Urea spray, Jul 18, 1946	67	4.5	1.4	24.7	0.181	—	—	1.3
Urea solution poured on ground Jul 18, 1946	63	5.1	1.5	29.2	0.176	—	—	1.4
Control	48	5.5	1.7	31.1	0.177	—	—	1.5
			1947					
Urea spray, Jul 24, 1947	64	10.0	3.0	56.6	0.177	3.19	-2.4	1.4
Oil-wax emulsion spray, Aug 4, 1947 and Aug 22, 1947	61	10.5	3.2	57.6	0.182	3.33	1.8	1.3
Control	45	10.2	3.1	57.2	0.178	3.27	—	1.6
			1948					
Urea spray, Jul 27, 1948 and Aug 28, 1948	64	6.9	2.1	42.7	0.162	3.16	-0.6	1.1
Oil-wax emulsion spray, Aug 12, 1948 and Aug 28, 1948	64	7.6	2.3	44.7	0.170	3.28	3.1	1.1
Control	48	6.9	2.1	45.4	0.151	3.18	—	1.1

*Calculated from average weight of grapes per vine.

TABLE III—EFFECTS OF UREA AND OIL-WAX EMULSION SPRAYS ON VIGOR AND YIELD OF CONCORD GRAPEVINES IN CLEAN CULTIVATION

Treatments and Dates of Application	Vines (Number)	Average Yield		Average Clusters Per Vine (Number)	Average Weight Per Cluster (Pounds)	Average Weight Per Berry (Grams)	Increase in Berry Weight (Per Cent)	Average Weight of Prunings Per Vine (Pounds)
		Weight Per Vine (Pounds)	Weight Per Acre* (Tons)					
			1946					
Urea spray, Jul 18, 1946	63	7.7	2.3	47.2	0.164	—	—	2.7
Urea solution poured on ground, Jul 18, 1946	62	8.3	2.5	50.4	0.164	—	—	2.6
Control	49	8.0	2.4	46.6	0.171	—	—	2.8
			1947					
Urea spray, Jul 24, 1947	63	15.4	4.7	77.9	0.198	3.24	1.2	2.8
Oil-wax emulsion spray, Aug 4, 1947 and Aug 22, 1947	61	14.6	4.4	72.6	0.202	3.39	5.9	2.6
Control	49	15.6	4.7	77.7	0.201	3.20	—	2.8
			1948					
Urea spray, Jul 27, 1948 and Aug 28, 1948	51	10.6	3.2	57.7	0.183	3.31	1.8	2.0
Oil-wax emulsion spray, Aug 12, 1948 and Aug 28, 1948	63	11.2	3.4	56.7	0.198	3.45	6.1	2.0
Control	51	10.4	3.1	57.3	0.181	3.25	—	2.0

*Calculated from average weight of grapes per vine.

compared with those from their adjacent control plots the differences were found to be small and inconsistent. In some instances the treated plot was lower in percentage of nitrogen than its adjacent control. It does not necessarily follow that the grape leaf is incapable of absorbing nitrogen supplied in urea sprays. The greener foliage and later shoot growth following urea sprays applied by Mack, Shaulis, and Smith (7) is strong evidence that the grape leaf has this capacity. Similar sprays applied by these same investigators in another vineyard in a different area, however, failed to produce any symptoms of absorption.

The importance of nutrient balance in plant nutrition has been emphasized by the work of Thomas and Mack (11), Shear and his coworkers (10), and others. The highly significant difference in average pruning weight between vines in the sod block and those in the cultivated block shows that two levels of vigor were represented in the experiment reported here and, possibly, two different intensities of nutrition; yet good leaf color was evident in both blocks in all three years. Percentage of leaf nitrogen in eight 1946 sod plots, including both treatments and the control, ranged from 2.60 to 2.75; in the eight adjoining cultivated plots the percentage ranged from 2.85 to 2.95. Although leaf analysis data are insufficient to establish the fact, it is suggested that the supply of nitrogen available to the vines in both the sod and cultivated blocks was in proper balance with other essential elements for the intensity of nutrition current in the respective blocks at the time the spray and soil treatments were applied. Since a nitrogen deficiency did not exist in either case, there was no increase in growth, yield, or size of berries.

Oil-Wax Emulsion Sprays:—In the Ladino clover sod block, plots receiving two oil-wax emulsion sprays in 1947, and two again in 1948, were not significantly better than control plots in yield, pruning weight, berry size, cluster size, or cluster number in either year (Table II). Although the average yield, berry size, and cluster size were higher in both years, the increases were neither consistent nor pronounced.

In the 1947 cultivated block, the 5.9 per cent increase in average berry size in the oil-wax plots over the control plots is a significant difference at the .05 level (Table III). These larger berries did not result in an increased average yield because the number of clusters per vine was smaller and the cluster size was not significantly greater.

The 1948 cultivated oil-wax plots showed an average 6.1 per cent increase in berry size over the controls (Table III). In addition to this increase the size of clusters in the oil-wax plots was significantly higher than those in the controls at the .05 level. Differences in pounds per vine and number of clusters per vine were not significant.

Refractometer readings on juice pressed from berry samples showed no difference in sugar content due to treatment. Berries in the oil-wax plots were dull purplish in color and felt spongy in comparison with berries in the control plots. Apparently the oil-wax sprays interfered with the usual development of the light blue bloom which is characteristic of the Concord variety. This would not be serious on grapes delivered to a processor but might lower their value in fresh fruit sales.

Langer (5) applied oil-wax emulsion sprays to Montmorency sour cherry trees at the first tinge of fruit color and again 1 week later. Sprays in our experiment were applied at an earlier stage in the development of the fruit with a longer interval between sprays. It is possible that different timing may produce greater increases in size of Concord grapes berries. Unless greater benefits than those reported here are obtained, the commercial use of the sprays would not be profitable. Since they must be applied later than solutions used to control insects and diseases, income from their use must more than cover the cost of the sprays.

Summary

One midsummer urea spray in each of two years and two in the third year failed to improve vigor or yield in either cultivated or Ladino clover sod blocks of a Concord grape vineyard receiving good care and adequate soil applications of commercial fertilizers. It is suggested that such sprays might be beneficial where a nitrogen deficiency exists.

Two oil-wax emulsion sprays applied annually over a 2-year period did not affect berry size and yield in the Ladino clover sod block of the same vineyard. Berry size was improved significantly by the sprays in the cultivated block. Treated berries were dull purplish in color and felt spongy, although their sugar content was not affected. Timing of the sprays may be important in producing maximum yield increases from the treatment.

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Longevity in California of American Grape Varieties Grafted on Various Rootstocks

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American native grape varieties are important mainly in the regions of the United States east of the Rocky Mountains. Commercial plantings are located, however, in several of the Pacific Coast States and in some of these areas phylloxera (*Phylloxera vitifoliae,* Fitch) may become an injurious pest to vines planted on their own roots. Rootstocks can be used to overcome the loss due to phylloxera injury. Quite frequently the question is asked, how long will American native grape varieties grow satisfactorily when grafted on resistant rootstocks?

The results of grafting American native grape varieties on rootstocks have been reported for eastern (2, 3, 7), southeastern (1, 5, 6), and central (8, 9) regions of the United States. In most cases greater yields of fruit and more vigorous vine growth have been reported for such grafted vines in comparison with own-rooted plants. Loomis (5) states that root troubles might be the explanation for the failure of own-rooted and grafted vines, but they give an indication of the longevity of many varieties on various rootstocks.

In 1912 a miscellaneous planting of American grape varieties grafted on rootstocks was made at the United States Experiment Vineyard, Oakville, California (4). One-year-old bench-grafted plants were used which had grown in the nursery row during the 1911 season. In most cases the plantings consisted of two vines of a variety on each rootstock but the same rootstocks were not used for all varieties. During the early years of the planting, some vines did not survive and missing vines were replaced with other available plants. At the end of 1948, the record in some cases represented one vine of the stock-scion combination. The stock-scion combinations listed have survived for the 36-year period, 1912–1948. Due to the small number of vines of each stock-scion combination, fruit weight records were not obtained. Growth ratings were taken to indicate whether the vines were making satisfactory growth. Ratings were given on a 1 to 10 basis, 10 representing very satisfactory growth.

Table I indicates the varieties and the rootstocks on which the grafts have made a satisfactory growth and have fruited satisfactorily over the 36-year period, 1912–1948. This table includes 48 scion varieties and 40 rootstocks. The rootstocks are listed after each scion variety in descending order of their growth rating. All combinations listed rated 7 or above on the basis of the 1 to 10 rating.

As indicated by Fig. 1, the varieties were still producing commercially good crops at the end of 1940, when the photographs were taken. Similar photographs could have been taken during the 1948 season. In Fig. 1 (a) is a vine of Concord on Rupestris St. George, with 18 pounds of fruit; (b) is Catawba on Solonis x Othello, No. 1613, with 20 pounds of fruit; (c) is Niagara on Mourvedre x rupestris, No. 1202, with 25 pounds of fruit; and (d) is Iona on Rupestris Othello,

TABLE I—AMERICAN GRAPE VARIETIES GRAFTED ON VARIOUS ROOTSTOCKS, WHICH HAVE MAINTAINED SATISFACTORY VIGOR FOR THIRTY-SEVEN YEARS AT OAKVILLE, CALIFORNIA. (NUMBERS REFER TO ALPHABETICAL LIST OF ROOTSTOCKS*)

Agawam—20, 38, 11, 35
Barry—36, 35, 38, 10, 11, 7
Black Pearl—32, 2, 15, 25
Black Eagle—39
Brighton—1, 13, 29, 16, 6, 5, 12, 19, 22
Brilliant—9, 19, 6, 36, 16
Brown—1, 39, 27, 18
Campbell Early—29, 14, 35
Catawba—35, 36, 14, 20, 10, 27, 18
Champion—33, 24
Chas. A. Green—18, 12
Concord—29, 28, 34, 19, 36, 35, 16, 18
Cynthiana—29
Daisy—1
Delaware, 16, 9, 29
Diamond—29, 3, 16, 14, 37, 20, 10, 27, 18
Diana—33, 38, 35
Downing—29, 14, 16, 15, 35, 23
Dutchess—29, 6
Early Victor—33, 24, 20
Eaton—32
Ester—21, 27
Eumelan—29, 16, 3
Fern Munson—24, 33
Gaertner—16
Geneva—10
Goethe—18, 16, 13, 5
Green Early—25, 26
Herbert—29, 31, 20, 8, 19, 11
Hexamer—33, 24, 37
Iona—9, 19, 16, 35, 10 6, 33, 14
Isabella—20, 36, 35, 18, 31, 13, 27
Jessica—33, 1
Lindley—16, 36, 6, 20, 5, 19, 35, 27, 30
Lucile—20, 38, 24, 37, 11
Mabel—34, 1
Massasoit—16, 12, 24
Maxatawney—19, 29, 9
Moore Early—29, 36, 19, 5, 18
Neva Munson—5, 24
Niagara—16, 29, 10, 27
Perkins—16, 17, 18, 24, 15, 33, 27
Rebecca—33, 29, 8, 24, 19
Salem—36, 29, 5, 16, 8, 6, 20, 38, 4, 13, 19
St. Louis—21, 40
Ulster—37, 27
Worden—36, 9, 30, 18, 6, 19
Wyoming—36, 18

*Alphabetical List of Rootstocks

1. Barnes
2. Berlandieri × riparia, No. 33 E. M.
3. Berlandieri × riparia, No. 420-A
4. Berlandieri × riparia, No. 420-B
4. (Bourrisquon × rupestris, No. 601) × Calcicola, No. 13205
6. (Cinerea × rupestris) × riparia, No. 229
7. Constantia
8. De Grasset
9. Dog Ridge
10. Joly
11. Judge
12. Monticola × riparia, No. 18804
13. Monticola × riparia, No. 18808
14. Monticola × riparia, No 18815
15. Monticola × rupestris
16. Mourvedre × rupestris, No. 1202
17. Mourvedre × rupestris, No. 1203
18. Riparia × (cordifolia × rupestris) No. 106 8
19. Riparia × rupestris, No. 101
20. Riparia × rupestris, No. 101-14
21. Riparia × rupestris, No. 108-103
22. Riparia × rupestris, No. 3306
23. Riparia × rupestris, No. 3309
24. Rupestris des Semis, No. 81-2
25. Rupestris Le Reux
26. Rupestris Mission
27. Rupestris Othello
28. Rupestris Pillans
29. Rupestris St. George
30. Rupestris × berlandieri, No. 301-A
31. Rupestris × berlandieri, No. 301-37 152
32. Rupestris × Cinerea
33. Rupestris × riparia, No. 108-16
34. Salt Creek
35. Solonis × (cordifolia × rupestris) No. 202 4
36. Solonis × Othello, No. 1613
37. Solonis × riparia, No. 1615
38. Solonis × riparia, No. 1616
39. Vermorel
40. Viala

with 19 pounds of fruit. The vines in this plot were planted 6 by 10 feet, making 726 vines per acre; with 3 pounds of fruit per vine, or slightly less, 1 ton of fruit per acre would be produced. On the basis of the above yields, from single vines, production would range from 6 to 8 tons per acre.

Since the number of vines of each combination of variety and stock was limited, a fine comparison of the value of the different rootstocks can not be given. The rootstock Rupestris St. George occurs more often in the leading position in Table I than any other stock. The rootstocks Mourvedre x rupestris, No. 1202, Solonis x Othello, No. 1613, Solonis x (cordifolia x rupestris), No. 202–4, Riparia x rupestris, No. 101–14, Rupestris x raparia, No. 108–16, Barnes, Dog Ridge, and others have also been satisfactory for the 36-year period. These grafted American native grape varieties have not only grown well, but, as Fig. 1 indicates, were especially good in fruit production.

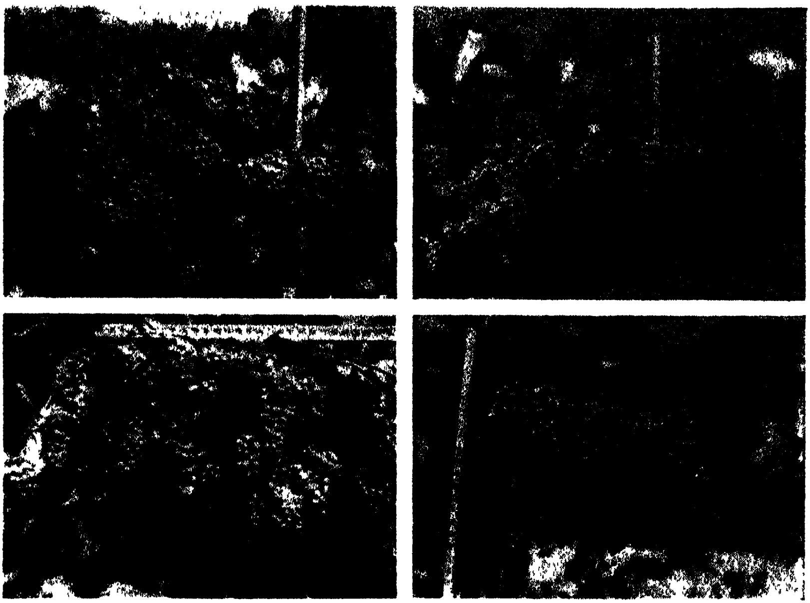

FIG. 1. Fruit production of American native grape varieties grafted on rootstocks at 28 years of age; (a) Concord on Rupestris St. George; (b) Catawba on Solonis x Othello, No. 1613; (c) Niagara on Mourvedre x rupestris, No. 1202; and (d) Iona on Rupestric Othella (Photographed in 1940).

SUMMARY

American native grape varieties grafted on certain rootstocks have made satisfactory growth and good fruit production over a 36-year period in California. Forty-eight varieties and 40 rootstocks, with a total of 191 stock-scion combinations, were growing well at the end of the 36-year period. This indicates that such grafted vines have a satisfactory longevity and also that lack of stock-scion affinity was not a major limitation in the longevity of these grafts.

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The Effect of Pinching Off the Terminals on Yield and Cane Growth of Champanel Grapes

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In 1942 two years' results of pinching the terminal growth of Champanel grapes at blossoming time were reported (3). Pinching significantly increased the weight of the fruit cluster by increasing the number of berries set; but in this limited experiment there was not a significant increase in total yield, which would normally follow.

In order to determine whether an increase in total yield would follow, a more extensive experiment was set up in April of 1944 in a uniform block of 2-year-old Champanel grape vines at the United States Horticultural Field Station, Meridian, Mississippi. Seventeen pairs of comparable vines were selected, on the basis of weight of prunings removed in February of that year. The vines were set 10 by 16 feet apart. They were pruned to spurs and trained to a Munson type trellis.

Champanel is one of the longest lived on its own roots of all varieties tested at Meridian, Mississippi (4). The fruit is large and of good quality for juice and jelly, but rather tart for eating fresh. The vine is extremely vigorous and fruit production has always appeared low in relation to its vigor. The Alabama Agricultural Experiment Station (2) reported increased yields following light pruning. Experiments in Mississippi (3) showed a great increase in fruit production of this variety by pruning to spurs, rather than to canes as eastern type grapes are usually pruned. This was due to the strong terminal dominance of the variety which results in growth from the terminal buds almost exclusively. Spur pruning increases the number of terminal buds and of bearing shoots and hence fruit production. Further increases in yield should be possible because of the extreme vigor of the variety, which vigor is largely wasted under orthodox methods of pruning and training. The tips were removed from all shoots on the treated vines at or immediately following blossoming time. This was done by pinching out the terminal bud with the thumb nail and removing less than ½ inch of growth from each terminal.

The data from the pinching experiment are presented in Table I.

TABLE I—Effect on Yields and Growth of Pinching Out at Blossoming Time the Terminal Growth of Seventeen Pairs of Champanel Grape Vines, Grown at Meridian, Mississippi

Year	Yields* Per Vine (Lbs)			Prunings** Per Vine (Lbs)		
	Treated	Check	Difference	Treated	Check	Difference
1944	10.6	7.6	3.1 ± 1.3†***	—	—	—
1945	23.7	19.9	3.8 ± 2.6	10.4	10.0	0.3 ± 1.5
1946	16.5	13.6	2.8 ± 2.4	7.4	10.6	3.2 ± 0.8‡
1947	8.4	6.1	2.3 ± 1.6	10.1	14.2	4.1 ± 1.4†
1948	26.8	23.4	3.4 ± 2.5	10.0	12.3	2.2 ± 1.4
1949	—	—	—	12.7	17.1	4.4 ± 1.0‡
Total	86.0	70.6	15.4 ± 6.3†	50.6	64.2	13.6 ± 4.1‡

*All data are means of 17 pairs; this causes occasional discrepancies of .1.
**Pruning weights were taken in the spring.
***Standard error of difference.
†Difference significant.
‡Difference highly significant.

Discussion

Pinching off the terminal growth at or just after blossoming time increased the yield over no treatment. This increase was significant the first year and for the sum of the five years, but it was not significant in any one of the last four years of the test. Pinching retarded growth, as measured by the weight of prunings removed, in four years out of five. This reduction in growth was significant for three years, and highly significant for the sum of the five years.

Increased fruit production normally results in less vegetative growth. Pinching is a form of pruning and pruning is a dwarfing process, so growth on the pinched vines would be retarded by both the increased production and by the pinching. The untreated Champanel vines produced more wood growth and less fruit for the five-year period.

The pinching did not stimulate the development of lateral growths from the pinched shoots. Only the apical bud developed, and the resulting canes were almost indistinguishable from those that had not been pinched.

Bioletti and Flossfeder (1) in California concluded that "pinching was devitalizing, and not advantageous, excepting on exceedingly vigorous vines, to promote the growth of fruitful laterals, or to reduce wind injury. Also continued topping or pinching year after year might almost ruin a vineyard". The results of the present test on Champanel are not in agreement with the results of Bioletti and Flossfeder, probably because Champanel is far more vigorous and less productive than the varieties that they used. However, they point out that the treatment should be used only on exceedingly vigorous vines. Champanel under the conditions of the present test appears to be such a variety.

Summary

In an experiment conducted over a five-year period at the United States Horticultural Field Station, Meridian, Mississippi, pinching off the terminal growth of spur-pruned Champanel grape vines at or just after blossoming time significantly increased the yield of fruit and decreased the weight of prunings. The treatment is recommended only for varieties that are excessively vigorous in relation to the amount of fruit produced.

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The Effect of Different Methods of Spur Pruning Upon the Production and Growth of Muscadine Grapes[1]

By N. H. Loomis, *U. S. Department of Agriculture, Meridian, Miss.*, and M. M. Murphy, and F. F. Cowart, *Georgia Agricultural Experiment Station, Experiment, Ga.*

Spur pruning of muscadine grapes has given greater yields of fruit than cane pruning, but no information is available to indicate the most desirable length to which the cane growth should be cut for maximum production. In order to obtain information of this character, tests were initiated both in Georgia and in Mississippi. At the Georgia Agricultural Experiment Station, Experiment, Georgia, in 1943, Hunt vines 15 years old were used. The test consisted of 21 vines selected for uniformity, as indicated by past yield records, and under a uniform cultural treatment. These were divided into three randomized treatments of seven vines each (seven individual vine plots). The treatments were:

I. Canes pruned to spurs about 4 inches long with two to four buds; 5 per cent or less of spurs entirely removed to prevent excessive crowding.
II. Same as I, plus removal of approximately one-half of spurs.
III. Canes pruned to spurs 8 to 10 inches long with seven to eight buds, plus removal of approximately one-half of spurs.

A somewhat similar test was initiated in 1944 at the United States Horticultural Field Station, Meridian, Mississippi, on 10-year old Thomas vines. The test included 32 experimental vines. The treatments consisted in varying the length of the spurs from one to four buds. There was one row in each treatment. The culture was uniform throughout this experiment, though different from that in the Georgia test. The results of the two tests are presented in Tables I and II.

Discussion

The total yields produced by vines receiving the different treatments did not differ significantly[2] in either test. Vines in the short spur pruning treatment at the Georgia station produced a greater yield than those in the other treatments. In Mississippi, vines pruned to 4-bud spurs yielded more than those pruned to shorter spurs. However, continued pruning to four buds per spur without thinning the spurs so weakened the vines that their vigor, as measured by weight of prunings removed at the end of the fifth season, was reduced. This reduction was significant excepting between the 2-bud and 3-bud treatments, and between the 3-bud and 4-bud treatments. Not only was the amount of growth reduced but the vines with the longer spurs de-

[1]A co-operative contribution approved by the United States Department of Agriculture; and by the Director, Georgia Experiment Station as No. 186, Journal Series.

[2]The data were analyzed by the Method of Group Comparisons as given by George W. Snedecor in "Statistical Methods."

TABLE I—EFFECT OF DIFFERENTIAL PRUNING TREATMENTS ON THE FIVE-YEAR AVERAGE YIELD OF HUNT MUSCADINE GRAPES (GEORGIA AGRICULTURAL EXPERIMENT STATION, 1943 TO 1947)

Treatment	Weight of Fruit	
	Pounds Per Vine	Tons Per Acre
1. Spurs about 4 inches long with two to four buds	80	5.7
2. Same as 1, plus removal of one-half the spurs	70	5.0
3. Spurs 8 to 10 inches long with seven to eight buds, plus removal of one-half the spurs	71	5.1

The vines were spaced 14 by 21 feet. Acre yield computations exclude the area occupied by non-bearing pollinating vines interplanted in the ratio of 1 to 7 as extra plants in the vineyard. These were allowed a total of 4½ feet of row space each.

TABLE II—EFFECT OF PRUNING TREATMENTS ON THE FIVE-YEAR AVERAGE YIELD OF THOMAS MUSCADINE GRAPES AND UPON VIGOR AS MEASURED BY THE AVERAGE WEIGHT OF PRUNINGS AT THE END OF THE FIFTH SEASON (U. S. HORTICULTURAL FIELD STATION, MERIDIAN, MISSISSIPPI, 1944 TO 1948)*

No. of Buds Per Spur	No. of Vines	Weight of Fruit		Weight of Prunings (Pounds Per Vine)
		Pounds Per Vine	Tons Per Acre	
1	8	42	5.1	14 ± 2 1**
2	8	45	5.4	8 ± 0.7
3	6	46	5 6	7 ± 1.5
4	10	53	6.4	5 ± 0.8

*The vines in Mississippi were spaced 16 by 10 feet. Acre yields are calculated upon the basis of one in nine vines being an unfruitful pollinator.
**Standard error.

foliated so early that the fruit did not color well nor ripen uniformly and its market value was considerably reduced. There was also a marked tendency toward alternate bearing by the long-spur vines. Whether these conditions would exist with other varieties has not been determined. At Experiment, Georgia, the Hunt variety pruned to spurs of two to four buds has, from all indications under the cultural practices employed, continued to produce heavy yields of good quality fruit over a period of several years. There was a greater tendency toward alternate bearing with the vines pruned to spurs of two to four buds with practically no spur thinning (treatment 1) than in the case of vines on which a comparatively large amount of spur thinning was done (treatment 2).

No records were taken on the size of berries or on the number of berries per cluster, but from casual observation there did not appear to be any difference in the size of fruit due to treatment. Not all buds on the longer spurs grew, whereas on the one- and two-bud treatments practically every bud grew and some adventitious or latent buds developed from the spurs and arms of the vines. Where the spurs were thinned or the spurs closely pruned more of the remaining buds developed and probably the clusters were larger, which would account for the small differences in yield between treatments.

The reduction in vigor caused by leaving more buds would indicate that a heavier rate of application of nitrogenous fertilizer would be advisable. Quite different results might be obtained if the experiments

were conducted at different fertilizer levels. The rate was 2½ pounds per vine, 375 pounds per acre, of 6-8-6 (N-P-K) fertilizer at Experiment; and 1½ pounds per vine, 408 pounds per acre, of 6-8-4 fertilizer at Meridian, excepting the last year when this was increased to 2 pounds per vine, or 544 pounds per acre.

Since neither the length of the spurs nor thinning the spurs as much as 50 per cent significantly affected the yields, the exact type of spur pruning used with muscadine grapes appears to be relatively immaterial so far as yield is concerned. Generally short spur pruning and some spur thinning facilitates cultivation, harvesting, and trellis upkeep. Hence the type of pruning should be determined by the vigor of the vine, the quality of the fruit, the ease of carrying on vineyard operation, and the personal preference of the operator.

Summary

Varying the length of the spur in pruning Hunt muscadine grapes and the removal of 50 per cent of the spurs did not significantly affect the total yield of fruit obtained in a five-year test at the Georgia Agricultural Experiment Station, Experiment, Georgia. Similarly varying the number of buds per spur from one to four did not significantly affect the total yield of Thomas muscadine grapes in a five-year test at the United States Horticultural Field Station, Meridian, Mississippi. The vigor of the Thomas vines as measured by weight of prunings removed at the end of the fifth year was the greatest for those treatments in which the vines were pruned the closest.

Further Experiments in Fertilizing Blueberry Hardwood Cuttings[1]

By C. D. SCHWARTZE and ARTHUR S. MYHRE, *Western Washington Experiment Station, Puyallup, Wash.*

IN AN EXPERIMENT (2) reported previously two of three fertilizers applied to blueberry hardwood cuttings in a peat-sand medium produced a desirable increase in top growth. Ammonium phosphate (11-48-0) gave better results than tankage and as good results as a prepared fertilizer containing major and minor elements. The results indicated the most desirable rate of fertilization to be somewhere between 30 and 60 pounds of actual nitrogen per acre. This experiment raised questions as to the importance of the source of nitrogen and the possible benefits of other major elements. In 1948 an experiment was set up to compare the effects of ammonium sulfate, ammonium nitrate, ammonium phosphate and sodium nitrate and combinations of these nitrogen sources with phosphorus and potash.

MATERIALS AND METHODS

Cuttings of the Jersey variety obtained March 27 were rooted in peat-sand (3:1) in sash-covered frames under a lathhouse. Duplicate lots were rooted with and without bottom heat. The frames were divided so that different fertilizers could be applied to lots of one hundred cuttings each. When secondary top growth indicated that the cuttings were rooted, fertilizers were applied in dry form to the surface of the medium between the rows of cuttings and the beds were watered. The beds with bottom heat were fertilized July 1; those without heat, July 22. Fertilizers were applied at rates required to supply 40 pounds of actual nitrogen per acre. The cuttings were taken up November 29–30, 1948. The fertilizer applications and the resulting top growth are shown in Tables I and II.

TABLE I—FERTILIZER RESPONSE OF JERSEY HARDWOOD CUTTINGS ROOTED WITH BOTTOM HEAT (100 CUTTINGS EACH LOT, SET MARCH 27, 1948, EXAMINED NOVEMBER 29-30, 1948. FERTILIZER APPLIED JULY 1)

Fertilizer Treatment	N-P-K Equivalent (Lbs Per Acre)	Rooting (Per Cent)		Shoot Length (Per Cent of Rooted Cuttings)			
		Good	Total	Over 18 In	12 to 18 In	6 to 12 In	Under 6 In
None—Check	— ——	83	92		6	58	36
Ammonium sulfate	40 0 0	85	93	16	35	34	15
Ammonium nitrate	40-0 0	94	96	18	35	39	8
Sodium nitrate	40 0 0	94	96	12	30	50	8
Ammonium phosphate (11-48)	40 175 0	91	93	19	34	40	7
Ammonium phosphate (16 20)	40-50 0	91	95	15	25	53	7
Ammonium sulfate, superphosphate	40-50 0	92	94	10	44	37	9
Ammonium sulfate, superphos., muriate of potash	40 40-40	86	91	14	23	52	11
Ammonium sulfate, superphos., sulfate of potash	40 40 40	88	92	15	24	45	16
Sodium nitrate, superphos., muriate of potash	40 40 40	80	89	10	27	46	17
Sodium nitrate, superphos., sulfate of potash	40 40-40	85	91	18	22	44	16

[1]Published as Scientific Paper No. 839, Agricultural Experiment Stations, Institute of Agricultural Science, State College of Washington.

TABLE II—FERTILIZER RESPONSE OF JERSEY HARDWOOD CUTTINGS ROOTED WITHOUT BOTTOM HEAT (100 CUTTINGS EACH LOT, SET MARCH 27, 1948, EXAMINED NOVEMBER 28–30, 1948; FERTILIZER APPLIED JULY 22)

Fertilizer Treatment	N P-K Equivalent (Lbs Per Acre)	Rooting (Per Cent)		Shoot Length (Per Cent of Rooted Cuttings)			
		Good	Total	Over 18 In	12 to 18 In	6 to 12 In	Under 6 In
None—Check	— —	78	90	—	—	52	48
Ammonium sulfate	40-0-0	86	91	3	19	51	27
Ammonium nitrate	40-0-0	88	93	3	16	45	36
Sodium nitrate	40-0-0	92	95	5	12	61	22
Ammonium phosphate (11-48)	40-175-0	90	94	4	16	55	25
Ammonium phosphate (16-20)	40-50-0	90	95	7	20	46	27
Ammonium sulfate, superphosphate	40-50-0	89	92	7	20	40	33
Ammonium sulfate, superphos., muriate of potash	40-40-40	85	91	6	12	57	25
Ammonium sulfate, superphos., sulfate of potash	40-40-40	85	90	2	20	50	28
Sodium nitrate, superphos., muriate of potash	40-40-40	82	89	3	19	53	25
Sodium nitrate, superphos., sulfate of potash	40-40-40	85	92	1	17	56	26

Shoot growth was increased by all fertilizer treatments in comparison with the unfertilized lots. Again, as in the previous year, no detrimental effects were observed. Nitrogen at the 40 pounds per acre level permitted adequate maturity of the shoots and roots so that the plants could be dug and handled in late November without breakage.

Essentially the same results were obtained with all four of the nitrogen sources. The addition of phosphorus and potash in either form did not have noticeable effect upon top or root development in comparison with lots treated with nitrogen only. As in previous experiments in the same location (3) bottom heat induced earlier rooting, permitting earlier fertilization and greater total plant growth for the season. In the unheated beds, approximately 27 per cent of the fertilized plants produced more than twelve inches of shoot growth. With bottom heat, over 60 per cent of the fertilized plants made shoot growth over twelve inches in length.

Increasing top growth in the propagating frame is worthwhile because it increases the salability of rooted cuttings. Most of the blueberry propagators in the Puget Sound area transfer rooted cuttings to peat-filled open frames where they are grown for another year before being sold or transferred to nursery rows in the field. Under these conditions the fertilization of cuttings will be of value only if it results in larger plants at the time that they are sold for planting stock. To determine this point, 24 Jersey plants representing an approximate average of those grown in a "check" treatment in 1947 and a like number fertilized with ammonium phosphate in the propagating bed were transferred to an outdoor peat bed in the spring of 1948. The two lots were set at the same spacing and received identical treatment, including fertilization with ammonium phosphate and frequent sprinkler irrigation. In January, 1949, total shoot length per plant was determined by measuring each shoot. The "check" plants had made shoot growth averaging 49.6 inches per plant while the larger plants from the fertilized propagating bed had made total shoot growth averaging 80.5

inches per plant. These measurements represent a conservative estimate of total growth which would be more accurately represented by volume than by length. The diameter of shoots is roughly proportional to their length and the longest and thickest shoots were produced on the "fertilized" plants.

On the basis of this experiment and the previous one, it may be concluded that propagation of the cultivated blueberry from hardwood cuttings in Washington is improved by fertilizing the cutting beds with fertilizers containing soluble nitrogen in the form of ammonium phosphate, ammonium sulfate, ammonium nitrate or sodium nitrate at a rate approximating 40 pounds of actual nitrogen per acre. With ammonium sulfate this rate requires only 2 grams per square foot or approximately ¾ ounce for a standard 3 by 6 foot bed. It seems likely that the detrimental effects sometimes reported have been the result of over-fertilization. The time of application does not seem to be very important so long as the fertilizer is available to the plants as soon as roots are formed.

It is worth noting that satisfactory results were obtained with mixed fertilizers containing muriate of potash, which is reported (1) to be injurious to blueberry plants and is not recommended for use on field plantings.

Summary

Desirable increase in growth of blueberry hardwood cuttings was obtained by fertilizing propagating beds containing peat-sand with fertilizers containing nitrogen in the form of ammonium phosphate, ammonium sulfate, ammonium nitrate, or sodium nitrate either alone or in combination with phosphorus and potash. The form of nitrogen or of potash did not affect the results. The increased shoot growth resulting from fertilizing the cuttings was still evident in 2-year-old plants. It is suggested that fertilizers be applied to cutting beds at rates that would provide approximately 40 pounds of actual nitrogen per acre. Propagators should exercise due caution to avoid over-fertilizing. Electric bottom heat resulted in earlier rooting and greater total response to fertilizers than was observed in unheated beds.

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A Preliminary Report on the Control of Mummy Berry (Sclerotinia vaccinii) in Blueberries by the Use of a Chemical Weed Killer

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THE mummy berry disease sometimes causes very heavy losses in blueberry plantations in Michigan and in other blueberry-producing states, both in wild and cultivated fields.

Darrow, Wilcox, and Beckwith (1) state that the disease is caused by the fungus *Sclerotinia vaccinii* Wor., and discuss its life history. Infected berries reach almost full size when they turn cream or tan in color and drop. Hard fungus structures (sclerotia) are formed within the fallen berries. The sclerotia may remain dormant for several years but if weather conditions the following spring are favorable each may produce one to several small, brown, toadstool-like growths (apothecia). If rains occur soon after the first leaves appear, spores are discharged from the apothecia which infect the new leaves. Conidiospores are formed on the infected leaves and young shoots. These in turn infect the flowers which later levelop mummied berries.

Literature with reference to the control of mummy berry is limited. Wilcox (2) reported in 1939 that "experimental sprays of bordeaux mixture and lime sulfur reduced, but did not control, the primary infection". Bailey *et al* in 1941 (3) stated that "the mummy berry disease was the most serious disease of cultivated blueberries in Massachusetts, and that spraying with 5-5-50 bordeaux mixture at the beginning and again toward the end of the blooming period seemed to be effective".

Darrow *et al* (1) in 1944 state, "spraying has been ineffective against the mummy berry disease. The control method most common in New Jersey consists in sweeping or raking the soil surface under the bushes and frequent tillage between the rows during the early spring when the spore-producing structures have started to form and before they have discharged their spores. The object of sweeping and tillage is to disturb the overwintering mummies at a critical period, thus stopping further apothecial development. An application of calcium cyanamide to the soil at the rate of 150 pounds or more per acre at the time of sweeping also seems to have been effective in rendering the mummies incapable of producing the spore-producing structures".

Bailey and Sproston (4) reported in 1946, "although control was not as good as desirable......Fermate appears to offer real possibilities for controlling the mummy berry disease".

Extensive spraying experiments have been tried by the writer at the South Haven Experiment Station. These included the use of lime sulfur, bordeaux mixture, Fermate, Dow "Mike" sulfur, Isothane, and Dithane. Copper and sulfur dusts were tried. Ground cover treatments have included granular cyanamide, cyanamide in dust form, Elgetol, and sulphate of ammonia. While all of these treatments have given partial control they have not been as effective as early and com-

plete cultivation. Another complicating factor is that blueberry plantations grow on rather wet land and heavy spraying equipment is bogged-down much of the time in early spring.

As this disease does not carry over in cankers or on blighted twigs, the vulnerable point from the standpoint of control, is to destroy the apothecia soon after they emerge from the ground and before they have discharged spores. This led to the use of Diesel oil and water fortified with Dow General Weed Killer (a concentrate of Dinitro-ortho-secondary-butylphenol) as a ground spray in the spring of 1948 to ascertain if it would kill the apothecia. The formula used was as follows:

Dow General Weed Killer	¼	gallon
No. 1 fuel oil	30	gallons
Water	100	gallons
Total solution	130¼	gallons

Comparative counts of diseased berries in the various treatments were as follows:

Treatment	*Total number Berries Examined*	*Number of diseased Berries*	*Percentage diseased Berries*
Check	1003	110	10.9
Clean cultivation and hoeing	1009	57	5.6
Dow General Weed Killer and oil ..	995	76	7.6

Only one spray of the Dow General Weed Killer and oil was used. It is believed from later work that a second spray about 10 days after the first would have reduced the percentage of infection still more.

Clean cultivation and hoeing must be completed before growth starts for effective control. This is often impossible in large plantations due to the limited time available and normally unfavorable weather conditions for this kind of work in early spring.

This experiment was repeated on a more extensive scale in the spring of 1949. Unfortunately, for the purpose of obtaining additional data, a dry spring resulted in no mummy berry infection in the check plots. However, it was clearly evident that the apothecia were killed on the sprayed plots. Healthy apothecia are light brown in color and turgid. After being sprayed the color changed to a dark, leathery brown, and shriveling of the tissues took place. Spraying into the crowns in early spring resulted in no injury to the plants. This material should not be used on the plant crowns later when the new shoots start emerging.

In these experiments only the strip occupied by the plants and about 18 inches on each side was sprayed. The row middles were cultivated to destroy any apothecia emerging there. Only a comparatively small amount of spray material is needed to spray the strip in the plant rows and light equipment can be used, thereby avoiding the problem of bogging-down that occurs with heavy equipment. Experi-

ments are under way in which the entire area between rows will be sprayed.

These experiments are to be continued with other weed killing materials.

While this paper is primarily for the purpose of reporting on a possible new method of control of the mummy berry disease, it should also be recorded that the use of the Dow General Weed Killer and oil aided greatly in weed control during the early spring. More extensive experiments are being conducted in cooperation with the Dow Chemical Company Research Laboratory at South Haven on weed control in blueberry plantations and will be reported on later.

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Growth and Yield Responses of the Temple Strawberry as Influenced by Plant Spacing, Width of Row, and Renewal Systems[1]

By R. G. Hill, Jr. and I. C. Haut, *University of Maryland, College Park, Md.*

The Temple strawberry variety recently introduced (3) because of its resistance to red stele, *Phytophthera fragariae, Hickman,* is becoming widely planted in Maryland's commercial strawberry areas. This paper reports the findings of an investigation to determine the growth and yield responses of the Temple strawberry to various plant densities; that is, thinning and spacing and width of row; and it also presents results of a second study of the same plots following three systems of renewal. Previous work concerning the adjustment of plant density by thinning, spacing and width of row with strawberries has been reported by Crane and Haut (1), Darrow and Dearing (2), and Schrader (4), among others.

Methods

The experimental blocks were fitted early in April 1946, by plowing under a dense cover of weeds and discing in 5–8–5 fertilizer at the rate of 1,000 pounds to the acre. The soil used was a uniformly fertile Hyattsville loam, with 2 to 5 per cent slope, well drained, and of a deposition type 48 inches deep. The field had been left untilled for several seasons and strawberries had not been grown in the area in recent years.

The experiment consisted of four replicate blocks separated by 3-foot aisles. Each block in the experiment consisted of 24 rows, 24 feet long, separated by 14-inch aisles. Within each block were randomized seven treatments of three rows each. The treatments consisted of 12-, 18-, and 24-inch thinned rows; 12-, 18-, and 24-inch matted rows; and 24-inch spaced rows with 9-inch spacing between plants. The entire experiment was surrounded by a 24-inch matted Temple row with aisles identical to those of the experiment. In all cases the distance between mother plants in the row was 24 inches.

The plants were set April 10 and 11, 1946. Cultivation and weeding were begun immediately and continued throughout the growing season. As soon as the runners began to form, about July 15, the spaced-row runner plants were pegged into position; all other runners were removed once the desired stand was obtained in the spaced row. The other rows were treated during the growing season by periodically placing runners back into the respective row areas. The thinned rows were treated on September 1, 1946, by raking out the unrooted runners and cutting them free with a circular edger. The matted rows were maintained by continually moving all runners formed into the area of the rows, so that all runner-plants were kept within the established limits.

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[1]Scientific Publication No. A253. Contribution No. 2188 of the Maryland Agricultural Experiment Station (Department of Horticulture).

Mulch was applied in the form of a 6-inch layer of wheat straw on December 2, 1946 and was removed on April 15, 1947. After the mulch was removed, sodium nitrate was broadcast evenly over the plot at the rate of 150 pounds per acre. The mulch, however, had to be reapplied on May 12 due to severe freezing weather. While some cold injury to early blossoms resulted, the damage was evenly distributed over the experimental area.

Plant population counts were made within three random square foot sections in representative areas of each row at the time of the initial mulch removal.

Harvesting began on June 6, 1947, and continued at 3-day intervals until June 27. After picking, the fruit was culled and only U. S. No. 1 grade was used for yield records. All records were made on the weight basis and later transposed to quarts. At intervals during harvest, random pound samples of fruit from each type of row were obtained and the number of berries therein counted to obtain a factor as to relative size of fruit.

When harvesting had been completed, three random square-foot sections of each type of row were carefully removed. The plants from these square-foot sections were washed free of soil, counted, and then dried at 70 degrees C for 3 days. The weight of the plants from each type of row was obtained and averaged to determine the relative size of plant in each treatment.

Following the fruiting season of 1947, three renewal systems were developed for second-year fruiting studies. These systems were as follows: (a) the original spaced row plants were maintained without allowing the development of additional runner-plants; (b) the matted rows were kept within the previously established widths and allowed to form as many additional runner-plants as possible; and (c) the thinned rows were permitted to revert to matted rows within the established widths. Throughout the summer, the plots were cultivated at approximate 2-week intervals.

A wheat straw mulch was applied on December 9, 1947, and was removed on April 22, 1948. The spring season was exceptionally favorable for berry production without severe freezes and with an ample moisture supply.

Harvesting commenced on June 2 and ended June 22, 1948. Yield records, dry weights, and population counts were obtained as in 1947.

RESULTS

The results of the investigation show that the Temple strawberry manifested definite responses in growth and fruiting behavior of the individual plant to modifications of the normal plant population by thinning and spacing practices.

The data presented in Table I shows the significantly different growth responses of the individual plant resulting from the treatments. Dry weight determinations showed the average size of the matted row plant to be 4.8 grams, while the thinned row was one and one-half times as large (7.0 grams), and the spaced row plant was 10 times as

large (46.1 grams). This difference in plant size may be partially explained by the differences in number of plants per unit area. The matted rows contained an average of 13.6 plants, the thinned rows 9.1 plants, and the spaced row 1.3 plants per square foot. Thus, by the methods employed the plant stand in the thinned rows was reduced 33 per cent over that of the matted rows. Plant spacing to the distance of 9 inches between plants reduced the plant stand to approximately one-tenth that of the matted row. The effect of these modifications of plant stand become much more apparent when considered in relation to the number of square inches allowed the individual plant for the supply of soil moisture and nutrients.

The fruiting behavior of the individual plant measured by yield of U. S. No. 1 berries shows equally marked responses to adjustments in plant stand. The matted row plants produced an average of 79.4 grams of fruit, the thinned row plants 105.9 grams, and the spaced plants 673.0 grams of fruit. Thus, on a plant basis the thinned row produced about one-third more fruit than the matted row and the spaced row more than nine times as much fruit as the matted row. Also on the individual plant basis, the narrower-row plants produced more fruit than the wider-row plants under the same treatment. The size of the fruit was also affected by thinning and spacing treatments. The spaced row plants produced fruit that averaged 66.6 berries per pound; the thinned row plants produced fruits that averaged 78.4 per pound, while fruits of the matted row plants averaged 81.9 per pound.

It is interesting to note that the spaced row plants were approximately 10 times as large, 10 times as fruitful, and had 10 times the area in which to develop as compared with matted row plants.

An analysis of variance of the yield data after transposition to an acre basis showed that there was no significant difference between the yields of the various treatments. The average yields of the matted rows were 4,452 quarts, the thinned rows 4,075 quarts, and the spaced rows 4,300 quarts to the acre.

The effects of the renewal systems applied to the first year plots again showed the definite responses of the Temple strawberry to modifications of plant population. All three systems of renewal resulted in an increase in plant size as compared to the first year (Tables I and II). Those increases approximated 67, 33 and 121 percent for the thinned, matted and spaced row plots respectively.

The renewal systems employed resulted in an increase in the number of plants per unit area except in the case of the spaced rows (Tables I and II). The greater increase in plant population of the thinned rows may be attributed to the larger, more vigorous plants existing at the close of the first fruiting season. This factor combined with the comparative lack of crowding in this treatment resulted in more vigorous growth the second year and more runner-plant formation.

The responses in fruiting behavior to these renewal systems showed the spaced-row plants to produce highly significant increases in yields over the matted and the thinned rows when compared on an acre basis. There was, however, no significant difference between yields of the

TABLE I—INFLUENCE OF WIDTH OF THINNED, MATTED, AND SPACED ROWS ON THE PERFORMANCE OF THE TEMPLE STRAWBERRY (FIRST HARVEST SEASON) 1947

Treatment and Width of Row	Plants Per Acre	Area Per Plant (Sq In)	Dry Weight Per Plant (Gms)	Yield US No. 1 Quarts (Acre Basis)	US No. 1's Per Pound	Yield Per Plant (Gms) US No. 1's
12-inch matted .	273,755	11 1	5 54	4,487	81	9.4
18-inch matted . .	333,648	9 8	4 81	4,358	81	7 5
24-inch matted	374,609	10.5	4.11	4,510	83	6 9
Average	327,337	10.4	4.82	4,452	81	7.9
12-inch thinned .	188,311	15 1	7 49	4,128	80	12.6
18-inch thinned .	229,501	15 1	6 61	4,177	78	10.4
24-inch thinned .	257,669	14 6	7.15	3,921	77	8.8
Average	225,160	14 9	7.08	4,075	78	10 6
Spaced .	33,204	108.2	46.13	4,300	66	73.4
L S D 5 per cent level			1 82	812		
L S D 1 per cent level			2.50	1,114		

TABLE II—INFLUENCE OF WIDTH OF THINNED, MATTED, AND SPACED ROWS FOLLOWED BY DIFFERENT SYSTEMS OF RENEWAL ON THE PERFORMANCE OF THE TEMPLE STRAWBERRY (SECOND HARVEST SEASON) 1948

Treatment and Width of Row	Plants Per Acre	Area Per Plant (Sq In)	Dry Weight Per Plant (Gms)	Yield US No. 1 Quarts (Acre Basis)	US No. 1's Per Pound	Yield Per Plant (Gms) US No 1's
			*Renewal B**			
12-inch matted	457,378	6 5	6 59	5,234	71	6 6
18-inch matted	581,947	6 1	7 13	5,376	69	5 3
24-inch matted	605,246	6 5	6.61	5,222	68	5 0
Average	548,190	6 3	6.44	5,277	69	5 6
			*Renewal C**			
12-inch thinned	376,960	7 6	12 80	5,512	56	8 4
18-inch thinned .	417,180	7 8	11.29	5,482	63	7.2
24-inch thinned .	481,446	8 2	11 46	4,670	65	5 6
Average	435,195	7 9	11 85	5,221	61	7.1
			*Renewal A**			
Spaced ..	33,204	108.2	102.25	7,072	57	122.2
L S D 5 per cent level			3 29	571		
L S D 1 per cent level			4 52	752		

*Renewal system described in text.

matted and thinned rows or between the various width of rows. The yields the second year were in all cases greater than those of the first fruiting season. This increased yield in the second fruiting season may be partially accounted for by the freedom from frost damage during the blossoming season and an adequate moisture supply. Probably the most important factor contributing to the increase in yield was that of the increased size of fruit (Tables I and II). The data showed that the first year harvest required approximately 17 per cent more fruits from a matted row, 27 per cent more fruits from a thinned row, and 15 per cent more fruits from a spaced row to make a pound of fruit, than did the renewal year harvest.

Summary

The investigation was undertaken in an attempt to determine the interrelationship of various widths of row and plant spacings upon the yield of the Temple strawberry and to determine the responses of this variety when grown under these conditions to different types of renewal systems. The results of the study conducted during 1946–48 reveal the following points:

1. Adjusting plant stand by thinning and spacing significantly increased the size of the individual plant and the number of fruits produced per individual plant.
2. Spacing plants increased the size of the individual fruits.
3. On the medium-light soil on which the study was conducted, there was no beneficial response as measured by acre yields in reducing the width of row of Temple strawberry from 24 to 12 inches.
4. In the first fruiting season, there was no significant difference in acre yields between the types of treatments applied. However, the renewed spaced row gave significantly increased yields over the renewed thinned, and matted row treatments.

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Winter Injury to Red Raspberries as Affected by Cultivation or Mulching[1]

By JOHN S. BAILEY, *Massachusetts Agricultural Experiment Station, Amherst, Mass.*

NUMEROUS papers have been published concerning the relative merits of cultivation versus mulching at cultural systems for red raspberries. So far as the author is aware no information has been published relative to the effect of these two systems on the amount of winter injury occurring. Since winter injury to red raspberries is a serious problem in Massachusetts, this point needs attention.

In the spring of 1942 a field at the experiment station in Amherst was set to the six varieties of red raspberries, Chief, Latham, Milton, Taylor, Washington and Marcy. In 1944 the field was divided in half. The west half was cultivated until mid-August when a cover crop was sown. The east half was given a fairly heavy covering of hay mulch. During the period 1943 to 1945 the whole area was uniformly fertilized with a liberal application of a 5–8–7 fertilizer annually. In 1946 each of these plots was sub-divided into halves. The south half of the cultivated plot has received each spring 15 pounds of nitrate of soda, equivalent to 225 pounds per acre. The north half has received 30 pounds. In addition, each of these plots was given 25 pounds of an 0–14–14 fertilizer at the time of sowing the cover crop. Of the two mulched plots the south one has received 15 pounds of nitrate of soda annually and the north plot none. Very liberal additional amounts of mulch have been put on the mulched plots from time to time. Each of the four plots is a little less than $^{1}/_{20}$ acre and contains two 21-foot rows of each of the six varieties.

All of the six varieties have suffered to some extent from winter injury. The two hardy varieties, Chief and Latham, have suffered much less than the tender varieties, Marcy, Milton, Taylor and Washington. Each spring estimates were made of the percentage of total cane growth killed during the winter. Differences in winter injury between the two systems of culture began to show in 1946. Table I gives the average percentage of winter injury for the six varieties.

TABLE I—AVERAGE PERCENTAGE OF TOTAL LENGTH OF RASPBERRY CANES KILLED BY WINTER COLD

	1943 and 1945		1946 to 1948			
	Cultivation	Mulch	Cultivation		Mulch	
Pounds of $NaNO_3$			15	30	15	0
Chief	12	13	10	16	11	11
Latham	10	13	11	15	16	17
Milton	51	52	30	30	64	74
Taylor	27	24	15†	14	54	53
Washington	53	44	54	50	58	73
Marcy	63	65	75*	65	82	64

*Only one year. Plants removed because of leaf curl.
†Only two years. Plants removed because of leaf curl.

[1]Contribution No. 710 Massachusetts Agricultural Experiment Station.

The differences in winter injury between the cultivated and mulched plots during the three-year period 1943 to 1945 are not significant. The 1944 data are not comparable with those of the other years and are not included in Table I. During the second three-year period, 1946 to 1948, the hardy varieties, Chief and Latham, show no significant differences in injury between the mulched and cultivated plots. On the other hand, the more tender varieties, Milton and Taylor, suffered much more winter injury on the mulched plots. The varieties Washington and Marcy were injured severely on both plots. These two varieties appear to be so susceptible to winter injury that cultural treatment made little difference.

In some of these varieties the differences in winter injury under cultivation and mulching have beeen reflected in the yields obtained. Table II gives the total yields in pints for each variety under the various treatments.

TABLE II—TOTAL YIELD PER VARIETY PER PLOT IN PINTS

	1943 to 1945		1946 to 1948			
	Cultivation	Mulch	Cultivation		Mulch	
Pounds of $NaNO_3$			15	30	15	0
Chief	115	61	69	67	89	98
Latham	97	76	29	46	60	70
Milton	51	49	84	91	38	46
Taylor	62	65	15†	52	58	50
Washington	43	24	66	71	27	28
Marcy	57	41	2*	37	57	38
Total	425	322				

*Only one year. Plant removed because of leaf curl.
†Only two years. Plant removed because of leaf curl

During the three-year period 1943 to 1945 the Chief and Latham varieties yielded considerably more in the cultivated than in the mulch plots. Since the mulch was not put on until the summer of 1944, it had not become well established during this period so that any effect would more likely be a retarding than a stimulating one. However, in the three-year period 1946 to 1948 the yields of these two varieties have dropped behind on the cultivated plots while on the mulched plots they have remained about the same or increased somewhat. With these two varieties where winter injury is not a factor, the mulched plots are now outyielding the cultivated. In the case of the Milton variety, the yield on the mulched plots equalled that of the cultivated during the first period. During the second period yield on the mulched plots was only half that on the cultivated plot. This is undoubtedly a result of the more severe winter injury on the mulched plots. Taylor has yielded equally well under the two types of treatment all through the experiment. It is probable that the reduction in yield resulting from winter injury on the mulched plots has been balanced by a reduction in yield resulting from reduced growth on the cultivated plots. The better yield of Washington under cultivation results from the better growth of this variety under cultivation. Under mulching it produces fewer large canes, the canes are more branched and tend to be more crooked and drooping. Winter injury to Marcy has been so severe

on all plots that yields have been low and there has been little or no difference between plots.

The differential fertilization with nitrate of soda within the mulched and cultivated plots appears to have had no effect on either winter injury or yield.

In conclusion, the points of especial interest are the failure of mulching to increase winter injury on the hardy varieties Chief and Latham and the considerable increase in winter injury on Milton and Taylor under mulch.

Chickweed Control in Strawberries With IPC[1]

By R. F. CARLSON and J. E. MOULTON, *Michigan State College, East Lansing, Mich.*

COMMON chickweed, *Stellaria media (L.) Cyrill,* is an annual problem in many strawberry plantings in localized areas in Michigan and in many other states. Further, chickweed grows profusely on a well-drained sandy loam which is the soil type on which strawberries are frequently grown. Because of its crawling growth habit, chickweed soon spreads between the plants in the row, crowding them. Within a short time (4 to 6 weeks) the weed becomes matted over the entire field making it impractical to eliminate it by manual or cultural means. Consequently, growers are in need of a selective herbicide that can be used safely and effectively to control chickweed and save the strawberry planting for a second and third crop.

Since chickweed is a winter annual, most of the seed germinates in early September in Michigan. The seedlings grow and spread rapidly during the fall and early winter both in the open field and under a straw mulch. By early spring a large number of seeds are produced which remain dormant during the summer and germinate when the conditions are favorable in the fall. Thus, many first-and second-year strawberry plantings are infested with the weed.

MATERIALS AND METHODS

During the fall of 1947 several herbicides including 2,4–D (2,4-Dichlorophenoxyacetic acid), Dow General (dinitro-ortho-secondary-butylphenol) and IPC (Isopropyl N-phenylcarbamate) were tried at herbicidal concentrations for the control of chickweed in strawberries. The "dinitro" compound was included because it had given promising performance when applied in the fall on annual weeds in strawberries (6), and the 2,4–D because of the resistance of strawberry plants to it (1). Because IPC had exhibited selective properties on grasses and some broad-leaved weeds it was also included (2, 4, 5). It also had been found that IPC killed common chickweed when applied at low concentrations (3 pounds per acre) to a lawn overgrown with the weed (3).

From these preliminary tests in 1947 it was found that IPC controlled chickweed; Dow General "burned" the foliage of both chickweed and strawberry plants; and 2,4–D showed no visual effect on chickweed. In the fall of 1948 the tests were limited to IPC at four concentrations, namely, 5, 10, 15, and 25 pounds per acre and at different intervals (September, October and November). Two locations were chosen in southwestern Michigan where chickweed is serious in many strawberry plantings. The soil type at one location was a Coloma sandy loam and at the other a Plainfield sandy loam. The Robinson variety was grown at one location and the Premier at the other, both plantings having been started the previous spring (1948).

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The technical grade of IPC was diluted with enough talc so that it could be dusted evenly over the strawberry rows. The material was applied at both locations on September 20, October 22 and November 12. At the date of the first application the chickweed was in the 2-leaved stage; at the second it was spreading over the ground; and at the third it was matted in and between the rows. Flowering of the weed began at the second application (October 22). The strawberry plants were vigorous and had numerous runner plants. At the time of the first application, September 20, it is probable that they were still initiating flower buds since that occurs during the month of September and well into October in Michigan.

At both locations the plots consisted of 25 feet of the row and two rows were used for each treatment. The rows originally were planted 4 feet apart and at the time of the applications were in a matted row about 18 inches wide. The dust form of IPC was applied with a small hand operated duster. Care was taken to distribute the dust evenly over the entire row where the weed is difficult to remove by hand pulling or hoeing. The check rows were weeded by hand.

Results

Effects on Chickweed:—At the time of the November applications, the chickweed in the plots treated in September were apparently dead at the higher concentrations (10, 15 and 25 pounds per acre). At the lower rate (5 pounds per acre) about 20 per cent of the chickweed was still alive. The chickweed in the treated plots appeared grayish, water-soaked as compared to the green vigorous growth in check rows. The water-soaked appearance was most pronounced on the 2- to 3-inch basal portion of the stem. Many of the leaves were dark green with a leathery appearance, and considerably thicker than leaves from untreated chickweed.

The chickweed treated October 22, had begun likewise to take on a slightly wilted and water-soaked appearance by November 12. On December 15 similar effects on the chickweed were noticed in the November 12 applications at all rates. At that time the weed in the earlier applications had started to turn brown.

The following spring (April 15) all of the chickweed in the 15- and 25-pound applications was dead and in the 5- and 10-pound rates about 80 to 95 per cent was controlled. This held true for all applications (September, October and November) and for both locations (Fig. 1).

Effect on Strawberry Plants:—A slight marginal color change (yellow) of the younger leaves was observed in November on the plants that had been treated in September. This change was most noticeable at the high concentration (25 pounds per acre). This effect was noticed also in the spring on plants treated with the high concentration and at different times the previous fall. Flowering appeared normal and occurred at the same time as the plants in the check rows. From general observations yield also compared favorably to the untreated hand-weeded check rows. No varietal differences were observed as to resistance to the material (IPC).

November 20, 2 months after the September applications, 20 plants

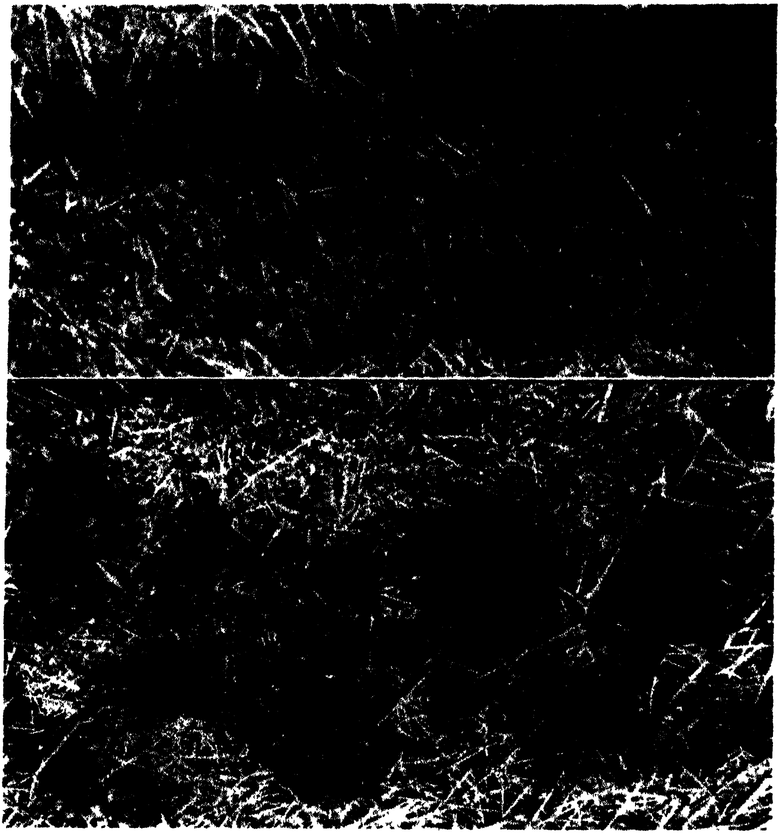

FIG. 1. Effective control of chickweed with IPC. Bottom row treated with 10 pounds of IPC per acre, and top row untreated. Treatments made in September and photographs taken the following May.

were dug from each treatment and from the check rows and were planted and grown in the greenhouse. At the time of transplanting, the plants were examined carefully for possible injury to the roots or crowns, but no visible effects were noticed. The plants grew normally and fruited in March in the greenhouse. After they had fruited they were dug and examined further. It was noticed that the roots of the plants that had been treated with 25 pounds of IPC per acre were injured, as was indicated by the dark color and the formation of a number of secondary roots at the base of the crown. The roots of the plants from the other treatments (5, 10 and 15 pounds per acre) appeared normal and vigorous, and in addition the root systems were more extensive and better developed than those of the check plants (Fig. 2).

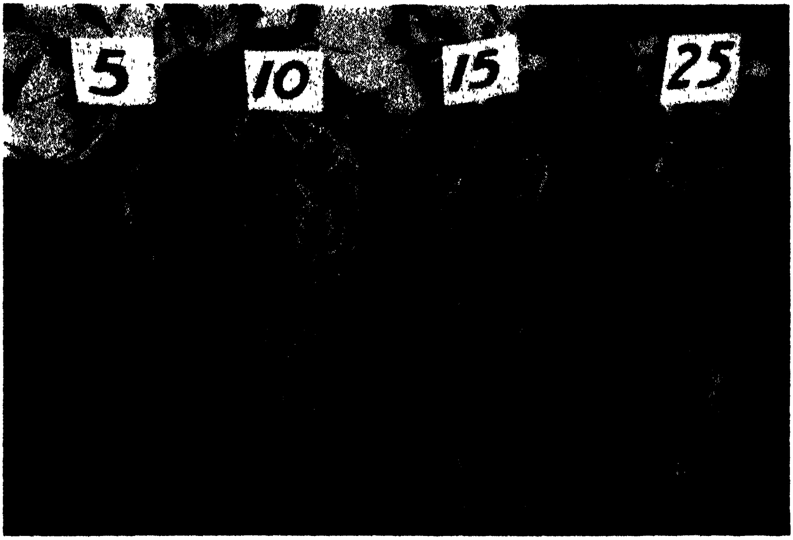

FIG. 2. Strawberry plants from rows that had been treated with 5, 10, 15 and 25 pounds per acre of IPC. Note, stimulatory effect of IPC.

SUMMARY

Four rates of IPC (5, 10, 15 and 25 pounds per acre) were applied at three different times (September, October and November) in 1948 and at two locations to chickweed growing in plantings of Robinson and Premier strawberries.

Satisfactory control of chickweed was obtained at all concentrations and from various times of application. The chickweed at first exhibited a water-soaked appearance at the basal portions of the stem and turned brown and died approximately 2 months after application.

Apparent yield of fruit from treated plants was equal to that of plants in hand-weeded rows. Some injury to the plants was noticed at the high rate.

Roots of strawberry plants appeared more vigorous from treated areas (5, 10 and 15 pounds per acre) than from check rows. Some injury was noticed on roots of plants from the higher rate (25 pounds per acre) of application which showed up as darkening of the roots and formation of new roots at the base of the crown.

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The Nutritional Status of the Cultivated Blueberry as Revealed by Leaf Analysis[1]

By John S. Bailey, C. Tyson Smith and Robert T. Weatherby, *Massachusetts Agricultural Experiment Station, Amherst, Mass.*

In the fall of 1946 a few blueberry plants in the University planting showed a marginal reddening of the leaves suggestive of a magnesium deficient condition. Chemical analysis of the leaves of apparently healthy and apparently deficient plants showed a magnesium content of 0.10 to 0.14 per cent on a dry weight basis. Such a low magnesium content, although it might have been a seasonal effect, suggested the desirability of further study.

In 1947 plots were laid out to determine the effect of magnesium sulfate applied broadcast dry at the rate of 500 pounds/acre and as a spray at 20 pounds/100 gallons. Each treatment was duplicated and untreated plots were left as checks. The soil pH varied from 4.3 to 4.9. Treatments were made July 10. On July 1 before treatment, leaf samples were collected for analysis. At the same time leaf samples were collected from vigorous, high producing bushes from three blueberry fields in the Cape Cod section. At each sampling leaves of the two varieties, Rubel and Pioneer, were collected. Each sample was a composite of leaves from several bushes. One or two leaves were picked from the mid-section of shoots of average length or a little over. The samples were taken to the laboratory, dried and analyzed for phosphorus, potassium, calcium, magnesium and in some cases nitrogen by official A. O. A. C. methods: Nitrogen by Kjeldahl, phosphorus by molybdate (volumetric), potassium by chloroplatinate, calcium by oxalate (volumetric), and magnesium by the pyrophosphate method. Differences between the varieties were small and inconsistent except for calcium which was slightly higher in Pioneer. Only the data for Rubel are presented.

The results of the analysis of the sample taken before treatment at the University and the samples from Cape Cod are given in Table I.

TABLE I—Percentage of Elements on a Dry Weight Basis in Rubel Blueberry Leaves Collected July 1, 1947.

Place	N	P	K	Ca	Mg
Cape Cod B	2.02	0.18	0.53	0.32	0.22
Cape Cod C	1.98	0.15	0.60	0.33	0.19
Cape Cod S	1.92	0.15	0.54	0.25	0.17
University	—	0.15	0.53	0.38	0.20

Since there are no leaf analysis data available for blueberries, an evaluation of these figures must be based on a comparison with other fruits. Nitrogen is about what one would expect in apple leaves of normal vigor. Magnesium would be considered almost down to a deficiency level. Potassium and calcium are very low compared to what one would expect in a healthy apple tree.

To see what effect, if any, the magnesium applications had, leaf

[1]Contribution No. 711. Massachusetts Agricultural Experiment Station.

samples were collected from the series of plots at the University on September 3, 1947. Results are given in Table II.

TABLE II—PERCENTAGE OF ELEMENTS ON A DRY WEIGHT BASIS IN RUBEL BLUEBERRY LEAVES COLLECTED SEPTEMBER 3, 1947 FROM PLOTS TREATED WITH MAGNESIUM SULFATE

	P	K	Ca	Mg
Soil application	0.10 0.11	0.53 0.49	0.61 0.60	0.20 0.22
Spray application	0.12 0.12	0.53 0.58	0.64 0.66	0.25 0.25
Untreated	0.11 0.11	0.57 0.56	0.56 0.53	0.21 0.22

The magnesium content of these leaves is high enough so that a deficiency would not be expected if blueberries behave like apples. Soil application of magnesium sulfate certainly did not increase the Mg content of the leaves. The spray applications appear to have increased the magnesium content of the leaves of these Rubel bushes in 1947 but there was no carryover into 1948. A similar comparison made in 1947 with the varieties Burlington and Atlantic gave the following percentages of Mg: Burlington unsprayed 0.19, sprayed 0.19; Atlantic unsprayed 0.22, sprayed 0.21. Since only one of the three varieties sprayed with magnesium in 1947 showed any increase in magnesium in the leaves, it is possible that Mg SO_4 is not readily absorbed through the leaf surface because of its waxy nature. Again, phosphorus, potassium and calcium are low, although calcium is about double that of the leaves sampled in July.

In July, 1948, leaf samples were again collected from the magnesium treated plots and analyzed. The results are given in Table III.

TABLE III—PERCENTAGE OF P, K, CA, AND MG ON A DRY WEIGHT BASIS IN RUBEL BLUEBERRY LEAVES IN JULY, 1948 FROM PLANTS TREATED WITH MAGNESIUM SULFATE IN JULY, 1948.

	P	K	Ca	Mg
Soil treatment	0.14 0.15	0.80 0.89	0.23 0.27	0.13 0.15
Spray treatment	0.13 0.13	0.87 0.82	0.27 0.31	0.16 0.16
Untreated	0.13 0.13	0.74 0.85	0.25 0.28	0.16 0.14

Here, again, it is obvious that the magnesium sulfate applications have not increased the Mg content of the leaves. Since the cultivated blueberry bush has such a shallow root system, it is rather surprising that enough of the magnesium was not taken up to cause a difference in the leaves. It is also apparent that in this case all the four elements are low compared with other fruits.

In order to get more information on what could be expected in good healthy, vigorous bushes, two more series of leaf samples were collected in the Cape Cod section in the summer of 1948, one series in July, the other in September. The bushes from which these samples came were all growing in well cared for and liberally fertilized fields.

The bushes were all large, mature bushes, shoulder high or over, and had every appearance of being healthy, vigorous and productive. The results are given in Table IV.

TABLE IV—PERCENTAGE OF P, K, CA AND MG ON A DRY WEIGHT BASIS IN LEAVES OF VIGOROUS, MATURE, RUBEL BLUEBERRY BUSHES IN THE CAPE COD SECTION IN JULY AND SEPTEMBER, 1948.

Date	P		K		Ca		Mg	
	Jul 19	Sep 7	Jul 19	Sep 7	Jul 19	Sep 7	Jul 19	Sep 7
Location								
1	0 15	0.09	0 64	0.60	0 20	0.34	0.12	0.11
2	0 14	0 08	0 57	0 86	0.23	0.31	0.14	0.14
3	0.14	0.08	0 68	0.54	0 21	0.45	0.13	0.14
4	0.14	0.08	0 58	0 46	0 29	0 43	0 17	0.17
5	0.13	0 09	0 54	0.56	0 29	0 54	0 16	0.19
6	0.13	0 08	0.53	0.51	0 23	0 37	0.12	0.15
7	0 14	0 09	0.60	0.76	0 40	0.66	0.15	0.18
8	0 15	0 08	0.53	0 51	0.21	0 45	0.14	0.16

These analyses show that, even in healthy, vigorous bushes, all four of the elements checked are lower than in other fruits. Phosphorus became extremely low in September. Change in potassium is inconsistent. Calcium increased, in some cases about doubling. There was little, if any, change in magnesium.

Discussion

Kramer and Schrader (3) suggested that because the highbush blueberry grows on an acid soil naturally low in exchangeable bases a low cation requirement is necessary for growth under those conditions. The low leaf content of potassium, calcium and magnesium found in these studies supports this theory.

Doehlert and Shive (1) suggested that the blueberry's need for magnesium is slight and that growth may be easily retarded by an excess. Doehlert and Mikkelsen (2) reported that where blueberry plants showed deficiency symptoms and were very low in magnesium "as little as 70 pounds of magnesium oxide per acre was sufficient to eliminate the leaf discoloration during the following season". Although the magnesium content of the leaves analyzed in 1947 was at or near what would be considered an adequate level for other fruits, it was consistently low in 1948. It is obvious that the plants which received a soil application of magnesium sulfate failed to reflect any absorption of magnesium as revealed by the content of their leaves. Although the leaves of both the check and magnesium sulfate treated plants seem to be low in magnesium in 1948 as compared with other fruits, they were no lower in this element than the leaves from vigorous, high producing bushes from the Cape Cod section. It is possible that the treated plants failed to show increased leaf magnesium because they had not yet reached the deficiency level.

Doehlert and Shive (1) also reported that the best nutrient solutions for blueberries were low in phosphate. The low phosphorous content of the leaves is a further indication of the blueberry plants' low requirement for this element. If the blueberry has a high anion requirement,

as suggested by Kramer and Schrader (3), the anions absorbed may be other than phosphate ions.

These results suggest that the blueberry's requirement for the four elements, phosphorus, potassium, calcium and magnesium, is lower than that for other fruits.

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A Method of Controlling Experimental Error for Perennial Horticultural Crops[1]

By J. A. RIGNEY, E. B. MORROW, and W. L. LOTT, *North Carolina Agricultural Experiment Station, Raleigh, N. C.*

WHEN an experiment is planned, the ideas in an experimenter's mind follow a pattern something like this: "Treatments *A* and *B* may have different effects. If they do, this difference can be measured by applying one treatment to one set of plants and the second to another set of plants". The observed difference in response of the two sets will afford a quantitative expression for the difference due to treatments, *provided* that the two sets of plants used and the environment are identical. If the two sets are not identical, the real treatment difference will be greater or less than that observed. It is possible to arrange the allocation of treatments so that the observed difference will be consistently greater or less than the real effects. This procedure of course will introduce a bias in the results. It is also possible to allocate treatments to sets of plants so that the observed difference will be equally likely to be too large or too small; that is, so that the results are unbiased. Furthermore, experiments can be designed so that one can state the probability that an observed difference deviates from the true difference by less than a certain amount.

Many aspects of the problems in designing experiments with perennial crops are common to all field tests. However, there are some that are peculiar to tree type crops. In the first place, plant to plant variation is as great as in annual crops, if not greater, but the number of plants than can be used is very restricted. Secondly, perennial plants remain on the same sites year after year and any variation in plant performance due to plot differences are likely to remain even if the test is run for a number of years.

This persistence of plant variation may be turned to the advantage of the experiment by proper planning. If the particular units that are to receive treatment *A* yield below those for treatment *B* *before* the treatments are applied, and this tendency persists throughout the duration of the experiment, the treatment difference can be adjusted accordingly. The statistical technique for making such an adjustment is called *covariance analysis*, and in many types of research has proven to be a powerful means of increasing experimental efficiency at a small cost. The technique is a standard one and is described in almost every text on statistics, yet it has not come into very wide usage. The reasons for the failure of this device to be more commonly used may be placed in two categories: (a) the unfamiliarity of investigators with the appropriate statistical techniques, and (b) the difficulty in obtaining adequate measures of the capacity of plants to produce prior to the application of treatments. The first category can be taken care of by edu-

[1]Contribution from the departments of Statistics, Horticulture and Agronomy, North Carolina Agricultural Experiment Station, in cooperation with the U. S. Department of Agriculture, Bureau of Plant Industry, Soils, and Agricultural Engineering, published with the approval of the Director as Paper Number 317 of the Journal Series.

cation, but the second requires actual research. This paper is directed toward the latter category.

In most of the orchard or vineyard experimental sites in the Southeast, soil gradients contribute a relatively small part to the total variation in the field that can be statistically controlled by the usual modern designs. By far the greatest source of variation seems to be of the random plant-to-plant kind. Fisher (1) has pointed out that this type of variation can be controlled by using level of production as a criterion for setting up replications or blocks. That is, high-yielding plants can constitute one replication, and lower yielding plants another, irrespective of their location in the area. However, this would mean that a single replication would not represent a compact unit of area, and the procedure would involve many physical inconveniences. Furthermore, there is no guarantee that the criterion used originally for forming replications would persist over several years. The obvious solution for this situation is to set up the experiments on the basis of the usual designs, such as randomized blocks or incomplete blocks of some kind. Then use any additional information that may be available to adjust treatment responses (2,3).

The problem of obtaining satisfactory supplementary information requires some thought. In most of the examples in the literature, uniformity yield data have been used. However, such information is usually non-existent for commercial orchards and to obtain it would delay initiation of the experiment. Furthermore, many fruit trees tend to produce in cycles of two or more years. Since all trees within an orchard are not at the same phase of the cycle, it would be a stroke of good luck if a single year's yield data were to be highly useful. However, there should be other measures of potential yielding ability of a fruit tree or plant that could be determined immediately prior to application of the treatments and that would be very effective in accounting for tree to tree variations. Two examples of the kinds of supplementary information that may be used will be given.

In 1941 ten fertilizer treatments per replication were tested on blueberries in eastern North Carolina. Three replications were used; the 10 plots in a replication consisted of five plants each. The site was in a commercial planting. All plants were pruned in the usual manner, as much fruiting wood being left on each plant as it seemed capable of developing. A count of the number of fruiting shoots per plant was made after pruning but prior to the application of the differential treatments. These counts were made only at the beginning of the experiment and were considered to be a measure of the initial bearing capacities of the plants. They were used to adjust yields in the covariance analysis of yields for each of two years. The results of this analysis are given in Table I. The variation in number of shoots accounted for 65 per cent of the plot variation in yields the first year. Without taking plant size into account, an observed difference between two treatment means would have had to be as large as 816 grams before one could be confident that one treatment was any better than another. By using the additional information, however, a difference of 443 grams led to the same conclusion.

TABLE I—ANALYSES OF COVARIANCE OF BLUEBERRY YIELDS (Y) IN 1941 AND 1942 AND NUMBER OF FRUITING SHOOTS PER PLANT (X) IN 1941.

	D. F.	Mean Squares ($\times 10^{-3}$) 1941	1942
Replications	2	2,335	2,255
Treatments	9	238	789
Error	18	250	390
Error adjusted for number of shoots	17	66	291
Percentage reduction in error due to covariance		65	31
L.S.D. without adjusting (gms)		816	1,084
L.S.D. after adjusting (gms)		443	930

It was of interest to see whether the differences in yielding capacity as estimated by number of fruiting shoots persisted for more than one year. As might be expected, the correlation was not so high the second year. Even so, using the 1941 estimates of plant size reduced the error by 31 per cent. There was quite a bit of "stunt" disease showing in the field the second year and this undoubtedly influenced the correlation to some extent.

There is an additional effect of the covariance analysis that should be noted. Treatment No. 7 yielded significantly higher than the *average* of the test in 1942, as is shown by the means in Table II. However, the number of fruiting shoots for this treatment was high in 1941 and the adjusted treatment mean is brought down considerably, though it still is the highest in the test. Nine of the 10 treatments in this experiment formed a 3 by 3 factorial. Treatment No. 7 was in this factorial set and there was no apparent reason for this particular treatment to be high. It is possible that a more adequate measure of bearing capacity might have eliminated the seemingly illogical effects of this treatment altogether.

TABLE II—AVERAGE YIELD AND NUMBER OF FRUITING SHOOTS FOR TEN BLUEBERRY TREATMENTS

Treatment No.	Average Number Shoots/Plant 1941(X)	Average Yield Grams/Plant 1942(Y)	Adjusted Yield Grams/Plant* 1942($\hat{Y}$)
1	60.9	3,167	3,047
2	54.1	2,679	2,822
3	47.7	2,216	2,606
4	58.5	2,899	2,872
5	59.1	2,762	2,712
6	56.0	2,940	3,009
7	72.5	4,032	3,465
8	57.9	3,112	3,108
9	54.0	2,259	2,406
10	57.3	2,741	2,760

*$\hat{Y} = Y - 38.6\,(X - 57.8)$

The second example of types of data that may be used to predict plant performance is taken from a study on Scuppernong grapes at Willard, North Carolina, in 1948. Five magnesium treatments were tested in four replications with plots of four plants each. In attempting to predict plant performance prior to treatment it was assumed that the general vigor and the total producing area of a vine should be closely related to yields, although their evaluation must of necessity be

subjective. Two approaches were used: (a) Each of the eight arms on each vine was visually rated from 1 to 5 for vigor and size (the highest score being the largest and most vigorous). This scoring was done independently by two observers. (b) The diameter of each arm was measured with calipers at a point 18 inches from the crown. In both cases the individual arm measures were cumulated for each vine.

Table III shows the results of using the various measures as estimates of producing capacity. The visual scores did a very effective job of predicting yield differences within treatments, accounting for about 60 per cent of the error variance. While this type of estimate may seem somewhat qualitative, its reproducibility is indicated by the similar high correlations for the two operators. Arm diameters were even a little more effective than the vigor scores, reducing the errors by 77 per cent which was not expected by the investigators. Another unexpected result was the effectiveness of the two measures when combined in a multiple covariance. In this particular case, 95 per cent of the total plot variation was predicted by these measures.

TABLE III—ANALYSIS OF COVARIANCE OF PRELIMINARY GRAPEVINE MEASURES AND YIELDS

	D F.	Mean Squares	Correlation
Replications	3	298	
Treatments	4	145	
Error	12	211	
Error adjusted for:			
Score (Lott)	11	84	.798
Score (Rigney)	11	72	.828
Arm Diameter	11	53	.878
Score (L) + Diameter	10	12	.975

It is not known for how long a period the estimates of yielding ability used for the grapes will be effective, but there is reason to believe that they will be more permanent than the type of measure taken on the blueberries. The blueberry fruiting shoot counts were subject to considerable variation in the pruning before the counts were made, whereas normal pruning should not seriously affect the vigor scores or the arm diameters of the grapes.

Again it is emphasized that these examples are given to demonstrate the usefulness of the covariance techniques even when the independent variable is such a subjective measure as visual scores. It is recognized that these particular measures may not be useful in other perennial crops or in different types of experiments with these crops. However, there is reason to believe that in most cases effective measures of original variation other than uniformity yield data can be obtained rather quickly and at little cost.

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3. Parker, E. R. Adjustment of yields in an experiment with orange trees. *Proc. Amer. Soc. Hort. Sci.* 41: 23–33. 1942.

Training Graduate Students in Horticulture in the South

By JULIAN C. MILLER, *Louisiana State University, Baton Rouge, La.*

DR. W. O. Scroggs, Dean of the Graduate School, Louisiana State University, in a paper written for the Alumni News said, "Dr. John W. Studebaker has aptly described the Graduate School as 'that unit of our educational system most directly responsible for stimulating research and for developing scholarly leadership' ". Dean Scroggs further states, "In this postwar period our peace, progress and general welfare depend more than ever before upon the fruitful results of research and upon the production of scholars with the capacity for effective intellectual leadership, and it is the duty of our Graduate School to help supply the country's need".

For the past 25 years the demand for trained personnel in colleges, universities, and agricultural experiment stations, as well as in industry, has made it imperative that men majoring in Horticulture have training beyond that required for the Bachelor of Science degree. For a while it was considered sufficient for one with a Master's degree to hold important positions of leadership, but usually those seeking younger personnel demand that the applicant have the training required for the doctorate. In order to obtain this advanced training it has been necessary for southern students to go to our northern colleges and universities. Some southern colleges and universities have attempted to give Master's degrees, but today, with the exception of Maryland, none has a staff organized to give training in Horticulture for the doctorate. The result of these circumstances is that southern students have gone to northern institutions for their training toward the doctorate. Those of us who have been trained in the North appreciate what these institutions have been able to do for us. The unfortunate fact remains that many of the better students find positions in the North, with the result that the South is losing not only a good student but a potential leader who would help develop southern horticulture. The southern student taking his graduate work in northern institutions generally conducts his research problem with some crop as grown in the North, and therefore he develops an interest in a subject that usually is not a problem in the South. The resulting fact is that, if the student comes back South, he requires some time to adjust himself to thinking of strictly southern problems.

There is an urgent need for a number of our leading colleges and universities to organize a well trained staff and to equip graduate and research laboratories in order that students from the South as well as other sections of the country may be trained for a doctorate in strictly southern problems. Fortunately, three institutions are now working to this end. A well equipped graduate school is not only needed for southern and other American students, but is urgently needed to train research workers of the subtropical and tropical regions since the problems there are similar to the problems in these areas. In the past, students from these areas have largely been trained in English, Dutch and German institutions which at this time are not able to take this responsibility.

It is the opinion of some of us that the present day curricula for most of the graduate students are not sufficient. The usual curricula for the graduate student consist of a given number of hours in two basic sciences in addition to certain courses in the chosen field. In addition to these requirements it is believed that the graduate student should have a good course in administration, advanced psychology, professional and personal ethics. Sooner or later the research worker has to take on the administration of his own activities as well as others. Certainly training in the above-mentioned subjects should advance the efficiency of his organization. For the past number of years the world has been in a turmoil and many of the ethical principles observed in the past have been set aside to a certain extent. It is the opinion of the speaker that research workers should be exponents of the highest moral and ethical principles. Any research worker visiting a laboratory should feel that all experiments and data can be shown to him without hesitation. Certainly all of us are benefited by frank exchange of personal ideas. The graduate student should be taught not only professional but personal ethics. He should be taught to appreciate what others have done for him. Here again, I would like to say that the vast majority of students show such an appreciation, but on the other hand a few do not; however, I think it is up to the graduate faculty to emphasize to the student the importance of cooperative relationship with his fellow workers.

Should all students working for the doctorate be required to gain a reading knowledge of French and German? Why not substitute additional work in English or Spanish, or permit equal credit in a number of subjects in his scientific field? As a substitute for languages should the student not be allowed to read a sufficient number of books in the classical and scientific literature in order to gain additional credit? Certainly, these are some of the subjects now being discussed in graduate school councils throughout the country. It might be that the man who takes the traditional languages as part of his training would be given a Doctor of Philosophy degree, while the student who would take additional scientific work might be given the degree, Doctor of Science, or some other similar title.

For the past 15 years a number of institutions throughout the South have been giving the Master's degree. At Louisiana State University over this period of time over 40 graduate students have been trained in Horticulture for the Master's degree and about one-third of these students have completed their work for their doctorate at other institutions throughout the country. While proud of the research conducted over this period of time, those associated with these graduate students feel grateful to have had the opportunity to help train these men. There is a definite need not only to train these students for a Master's degree but also to give them an opportunity to study for their doctorate. Certainly a number of our students should be sent to the northern institutions, but, at the same time, some of the northern students should come South. A free exchange of outstanding students from various sections of the country, as well as the world, makes for a better understanding of research as well as harmonious relationship, both of which would make for intelligent leadership by clear-visioned, well-trained men capable of straight thinking.

Adaptation of Punched Cards for Filing Horticultural References

By DAVID G. WHITE and J. L. MECARTNEY, *The Pennsylvania State College, State College, Pa.*

THE manner in which horticulturists maintain their references has become increasingly complicated with the increment of many new subjects. Many publications require a minimum of three or more reference cards to be properly cross-indexed. Without cross-indexing the value of a reference card system is materially reduced but unfortunately cross-indexing is so bothersome that most of us probably do no more of it than seems absolutely necessary. As a result we cannot readily find all the literature in our files on any particular subject.

For several years government agencies and numerous industries have employed cards punched with holes adjacent to the margins for filing information concerning their personnel or other subjects. Each hole or combination of holes is assigned to a specific detail and the pertinent details on an individual card are identified by cutting notches or slots in the place of the holes. The notched card or cards will drop out of a group of cards which are not notched in the same place whenever a needle-like sorter is passed through all the identical holes. Machines are used to sort a large number of cards and hand sorters are used with smaller volumes. Cross-indexing of an individual card is done by cutting notches for all the pertinent details with a hand-slotting punch designed for that purpose[1] (see Fig. 1).

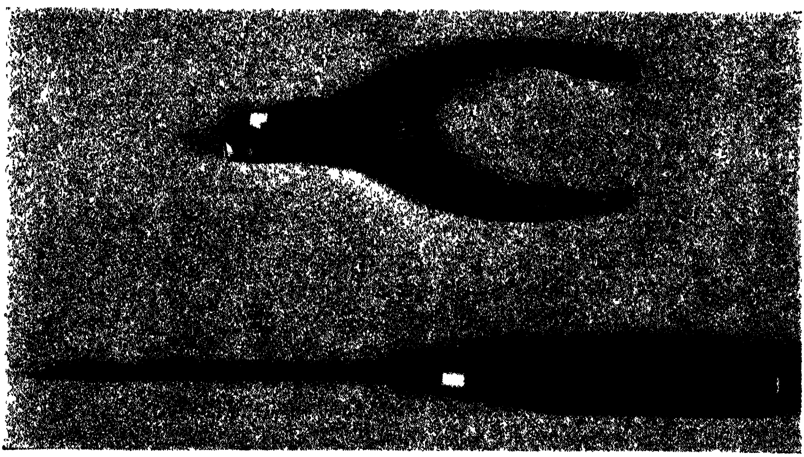

FIG. 1. Above, the hand-slotting punch designed for notching cards. Below, the hand sorter used to separate desired cards.

[1]Cards and accessory equipment are manufactured by the McBee Co., Athens, Ohio, and the Charles R. Hadley Co., Los Angeles, Calif. There may be other manufacturers not known to us; mention of the above companies is not to be construed as a specific recommendation.

The adaptation of punched cards for filing horticultural references seems advantageous since the system permits the maximum amount of cross-indexing with the minimum amount of effort and has proven to be rapid for locating all references to any particular subject. Cards 5 by 8 inches in size furnish sufficient space for abstracting most articles and are somewhat easier to handle than smaller sized cards. The preparation of a key relating subjects to the marginal holes was rather complicated. The particular key in our system was designed specifically for pomologists but it could be augmented to include all phases of horticulture or it could be modified to suit some phase of horticulture other than pomology. In fact one important advantage of this key is that a large number of additional details may be added any time.

It is possible to notch each index card for both the subject or subjects concerned as well as for the particular fruit or fruits concerned (see Fig. 2). In our system the holes on the left-hand margin and the upper holes of the right-hand margin are assigned letters of the alphabet, to and including X. The letters are indicative of the following general subjects:

A — Chemistry
B — Minerals and Nutrition
C — Soils
D — Cultural practices and fertilization
E — Pruning, brush disposal, tree removal, wounds
F — Blossom dates, dormancy, ecology, meteorology
G — Fruiting, pollination, thinning
H — Harvesting, grading, packing, packages
I — Transportation, storage, processing
J — Varieties, exhibits, districts
K — Parasitic diseases
L — Invertebrate pests
M — Control of diseases and invertebrate pests
N — Vertebrate pests and control
O — Seeds
P — Propagation and planting
Q — Growth phenomena and light relations
R — Respiration, translocation, transpiration
S — Synthesis and other physiology
T — Anatomy, morphology, genetics, and other botany
U — Apparatus, methods, techniques, terminology
V — Construction, economics, teaching, miscellaneous
W — Not assigned
X — Not assigned

Each general subject is sub-divided by the numbered holes at the upper margin of the card. The reader may reconstruct all the subdivisions from the alphabetical key given at the end of the article, if he wishes to do so. For example, a reference card relative to "Minerals and nutrition" is notched at the letter B for this general subject. Fur-

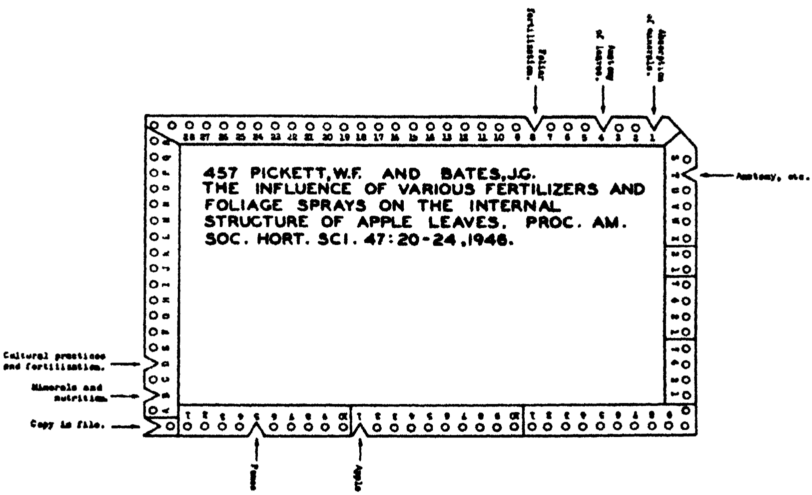

FIG. 2. The punched card illustrated above is cross-indexed according to the key submitted with this article. This card would fall out from a mass of cards if a sorting needle were passed through the holes for any of the subjects notched on the margins. With the ordinary card filing system several cards would be required to index this reference with equal thoroughness. The number "457" before the authors' names indicates the number of the reprint in a personal collection.

ther refinement is gained by notching an upper hole at one or more of the following numbers:

1 — Absorption of minerals	2 — Foliar analysis
5 — Balance of minerals	2 — Leaf analysis
2 — Deficiencies of minerals	3 — Micronutrients
2 — Diagnosis of deficiencies	1 — Mineral absorption
5 — Mineral balance	6 — Radioisotopes
2 — Mineral deficiencies	4 — Toxicities of minerals
4 — Mineral toxicities	3 — Trace elements
3 — Minor elements	6 — Tracer elements

The repetition of numbers is intentional because they represent the same or similar subjects as they appear in alphabetical arrangement in the master key. Thus, the subject "Absorption of minerals" and "Mineral absorption" are both assigned the code "B–1". A reference dealing with the absorption of minerals would be notched at the left margin at "B" and on the upper margin at "1". In this particular general subject only 6 of the 30 possible numbers on the upper margin are used and 24 other sub-divisions could be added. Similar expansion is possible in each of all the other general subjects. In addition, the letters "W" and "X" have not been assigned a general subject and are open for future use. In all instances the cards on any general subject can be separated by passing the sorting needle through the holes corresponding to the

letter assigned the subject. A second pass of the sorting needle through an upper hole corresponding to a number assigned the sub-division will separate those cards. Two passes of the sorting needle are the minimum feasible and this is a distinct advantage in comparison with the customary three or more passes required by most systems.

The value of the punched card does not end with the indexing of subjects since the holes at the bottom margin are utilized for reference to the individual plants. If the card is turned upside down, three sets of digits in groups of 10 are apparent. The right-hand set is keyed to major plant divisions as follows:

0 — Drupes
1 — Field crops
2 — Unusual economic crops
3 — Nuts and forestry
4 — Ornamentals
5 — Pomes
6 — Small fruits
7 — Sub-tropical and tropical fruits
8 — Vegetables
9 — Miscellaneous crops
10 — Not assigned

The center set of 10 digits is used to sub-divide the above major plant divisions. For example, number 6 refers to small fruits and number 1 following the 6 refers to brambles. The left-hand set of digits further sub-divides the brambles; for example, number 1 as the third number would indicate blackberries. In the index key blackberries would be referred to as "611". Many plants, such as apples, are listed under only two digits ("51") and in all cases additional plants could be assigned numbers without duplication. The plant classfication is recognized in the key by absence of letters.

On the right-hand margin of the card below the letter "X", sufficient digits remain to indicate the first two letters of the author's name, if desired. Various combinations of digits can be used for this purpose. It would be possible to utilize the same set of digits to indicate the year of publication rather than the author's name. We have preferred to leave this space unassigned for the present.

The extra hole on the left-hand at the bottom margin can be used to indicate whether a copy of the reference is in the files. The user of the punched card filing system may employ only part or all of the different indices described. In all instances, however, it is necessary that the correct notches be made or else the card will not be separated when desired.

We have found it convenient to file the cards according to the general subjects listed previously because the majority of references require indexing for only one subject. Cards which are notched only for a plant, such as "Strawberries in Pennsylvania", are filed separately as plants having no particular subject. Cards which have been notched for two or more general subjects are filed as a group separate from those filed under single subjects. In this manner fewer cards are handled in sorting, although the entire mass could be filed without

segregation and individual cards located by "needling" the entire mass.

Our key to the index system is condensed alphabetically within a "Zephyr Autodex"[2] (see Fig. 3). These gadgets are ordinarily used

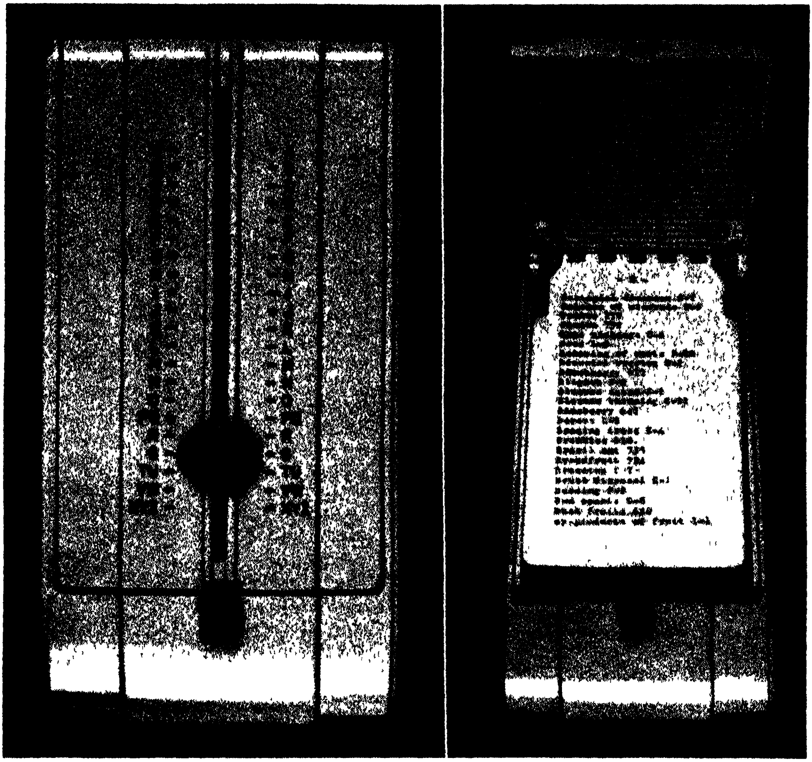

FIG. 3. The "Zephyr Autodex", open and closed, which condenses the alphabetically arranged index key in a convenient and easily accessible manner.

for rapid access to telephone numbers or addresses. We have found them most convenient as the source of the index key because so little desk space is required and the code number of any item can be located rapidly. The key to the index system is listed on the following pages.

[2]Manufactured by the Zephyr American Corporation, New York, N. Y. Similar gadgets are manufactured by other companies and are available in book stores.

The Key Used for the Adaptation of Punched Cards for Filing Horticultural References

Abscission S-1
Absorption of Minerals B-1
Absorption of Water B-1
Adaptations of Fruits V-2
Aeration of Soil C-1
After-ripening of Seeds O-1
Akee 731
Almond 01
Alternate Bearing G-1
Analytical Methods A-1
Anatomy of Buds T-1
Anatomy of Flowers T-2
Anatomy of Fruit T-3
Anatomy of Leaves T-4
Anatomy of Roots T-5
Anatomy of Stems T-6
Animal Manures D-1
Annual Flowers 411
Annual Legumes 111
Annual Non-Legumes 121
Anthracnose K-8
Aphids L-1
Apomixis O-3
Apparatus U-1
Apple 51
Apple Scald I-6
Apricot 02
Auxins Q-1
Avocado 71
Bacterial Diseases K-1
Balance of Minerals B-5
Bamboo 21
Banana 732
Base Exchange C-2
Bees L-2
Behavior of Roots P-12
Biennial Bearing G-1
Blackberry 611
Blights K-2
Blossom Dates F-1
Blossom Thinning G-11
Blueberry 641
Borers L-2
Bracing Trees E-4
Brambles 61
Brazil Nut 733
Breadfruit 734
Breeding T-7
Bridge Grafting P-1
Brush Disposal E-1
Budding P-2
Bud Sports T-8
Bush Fruits 62
By-Products of Fruit I-1
Cacao 735
Cane Fruits 61
Cankers K-3
Canning Fruit I-2
Carambola 736
Carbohydrate Synthesis S-2
Carob 737
Cashew 738
Ceylon Gooseberry 739
Chemical Composition A-2
Chemical Soil Analysis C-3
Chemical, in General A-3
Chemotherapy M-1
Cherimoya 741
Cherry 03
Chestnut 31
Chicle 22
Chilling Requirements F-2
Chimeras T-8
Chinquapin 31
Chlorophyll Synthesis S-3
Cinchona 231
Cinnamon 271
Citrus 72
Classification of Soils C-4
Climate F-8-9-10
Coconut 742
Codling Moth L-4
Coffee 743
Colchicine T-7
Cold Injury F-4-5
Cold Storage I-5
Color Measurements U-7
Color of Fruit G-2
Color of Leaves B-2
Composition, Chemical A-2
Composting of Soils C-5
Conduction R-3
Construction Operations V-1
Contact Poisons M-2
Containers, Fruit H-1
Contour Planting P-3
Control of Erosion D-4
Control of Insects M
Control of Weeds V-2
Controlled Atmosphere I-6
Correlations, Growth Q-2
Costs of Production V-3
Cover Crops D-2
Crabapple 52
Cracking of Fruit G-3
Cranberry 642
Culinary Products I-10
Cultural Machinery D-3
Cultural Methods D-2
Curculio L-5
Currant 621
Cuttings P-4
Dates 744
Dates of Blossoming F-1
Deer N-1
Deficiencies of Minerals B-2

Isolation of Lycopersicon Esculentum Type Tomato Lines Essentially Homozygous Resistant to Root Knot[1]

By W. A. FRAZIER and ROBERT K. DENNETT, *University of Hawaii Agricultural Experiment Station, Honolulu, Hawaii*

THE initial work at the Hawaii Station on breeding tomatoes for nematode *(Heterodera marioni)* resistance has been discussed by McFarlane, Hartzler, and Frazier (9). Derivatives of the T–1427 cross described in that report were carried for several generations, under rigorous testing against root knot susceptibility, until lines were isolated which had a very high degree of resistance. However, all selections were highly incompatible with *Lycopersicon esculentum*. Further crosses of T–1427 derivatives to 4N *L. esculentum* were readily secured but while they were under test two promising lines heterozygous for nematode resistance were secured from Dr. Victor M. Watts of the Arkansas Agricultural Experiment Station (12). The compatibility with *L. esculentum* and the type of resistance present in this material, originating from the hybrid made by Dr. Paul G. Smith of the California Agricultural Experiment Station (10), proved of such promise that work with the T–1427 derivatives was suspended. In this paper a brief summary of data showing the degree of resistance finally secured in the T–1427 derivatives and behavior of the Smith-Watts material selected and further hybridized to commercial types in Hawaii will be presented. In the latter case, presentation of data will be confined largely to the relatively few selections which, as will be shown, have a degree of resistance apparently not yet shown previously for compatible *L. esculentum* type tomatoes.

MATERIALS

1. *T–1427 Derivatives:*—Four selections — 2848, 2947, 2948, and 2949 — from the T–1427 (9) cross, [(*Lycopersicon hirsutum* × Bonny Best) × (Bounty × BC–10)] × *L. peruvianum* (PI 128645) were included in advanced-generation studies for resistance.
2. *4N Lycopersicon esculentum × 2N T–1427 Derivatives:*—The F_1 behavior of this cross is discussed under "results".

[1]Published by permission of the Director of the Hawaii Agricultural Experiment Station as Technical Paper No. 188.

The significant basic work in transfer of the gene or genes responsible for root knot resistance to *Lycopersicon esculentum* compatible types was done by Paul G. Smith of the California Agricultural Experiment Station and Victor M. Watts of the Arkansas Agricultural Experiment Station. The selections carrying combined resistance to spotted wilt, fusarium wilt, and gray leaf spot used for hybridization with the nematode resistant material were developed under the general tomato improvement project at the Hawaii Agricultural Experiment Station. K. Kikuta, J. W. Hendrix, J. S. McFarlane, S. Tachibana and M. Matsuura have all contributed materially to the program.

[2]For purposes of brevity the letters HES, referring to Hawaii Agricultural Experiment Station selections, will be deleted hereafter.

3. *HES 3386 and Progeny:*—In 1944, Smith (10) reported the successful embryo culture of a cross between Michigan State Forcing (*Lycopersicon esculentum*) × *L. peruvianum* (P.I. 128, 687). Watts (12) secured cuttings of this F_1 hybrid and made backcrosses to *L. esculentum*. Of three backcross plants obtained two were highly resistant to root knot, and one of these, Cr 2–45–2, was self-fertile. Seed from this plant, CR–3A, and of a derivative designated Cr 46–8–2S, were sent to the Hawaii Station by Watts. Fourteen selections were made from Cr 46–8–2S, and six from Cr–3A. Only one plant, given a Hawaii selection number HES 3386[2], gave progeny all of which appeared to be highly resistant. It came from line CR–3A, and fortunately an immediate cross to a three-way resistant (6) type was secured even though the excellent resistance of the 3386 mother plant was not known at the time. Resistance of F_3 and F_4 selections from this cross, 3962, 3963, 3999, and 4000 is shown in this paper.

Methods

Seedling tests were carried out either in gallon cans, No. 2½ cans, or flats (3-inch depth) filled with sterilized soil (two-thirds soil and one-third coral or black volcanic sand). Tile beds described by McFarlane, *et al* (9) were also used, in which case soil was treated with chloropicrin (100 to 300 pounds per acre rate) several days before application of root knot galls. Thoroughly chopped galls from tomatoes or other susceptible plants were placed in the soil, covered with ½ to 1 inch of soil, and seeds planted immediately over the rows of inoculum, or, as in some recent cases, seeds were planted 3 or 4 days after the placement of inoculum. Prior to placement in soil, inoculum was dipped in a cuprous oxide suspension (1½ to 2 teaspoonfuls per gallon); seeds were treated with cuprous oxide; also young seedlings and soil were thoroughly drenched with the suspension of cuprous oxide, at frequent intervals after emergence, to control damping off. In spite of these helpful precautions, used previously by Bailey (1), death of some plants occurred as a result of damping off organisms.

Decay of root systems, resulting in many cases in only a stub remaining, has been common. Accurate root knot readings often can not be obtained with such plants, so that further studies of means of sterilizing root knot galls against the organism or organisms involved, without killing eggs or larvae of *Heterodera marioni*, are needed. Further work on time of sowing seed in relation to time of application of inoculum and effects of various media in which seedlings are grown should be helpful, also.

After root knot data on seedlings were obtained, the plants were transplanted to a field heavily infested with nematodes. Field tests with non-inoculated susceptible plants were repeatedly observed to give less reliable results, however, than artificial infestations obtained from sterilized soil.

Weight of ground-up root knot galls applied was generally from 20 to 50 grams per linear foot of row or per 2½ or 1 gallon can. This is

a heavy application, and has contributed, along with the root rotting organisms, to stunting and chlorosis of seedlings through nutrient starvation. Applications of a nutrient solution were therefore necessary to at least partially offset this condition.

Seedlings have been grouped into four classes, depending upon degree of galling as follows: 0, completely free of galls of any kind; 1, slight galling (in recent tests the number 1 class has been divided into plants showing one, two, three, or four or more galls); in previous tests the number 1 class also included plants with only one, two, or three galls, but data were not taken to show these minor variations; 2, medium galling; and 3, severe galling. A fifth, question mark, category has recently been added for plants which show indications of slight root swelling that may or may not be caused by nematodes. Such plants had previously been placed in class 0.

Soil temperatures, recorded at various times at depths of 2 to 3 inches in the various containers and soils used, ranged from a minimum of 63 to 75 degrees F at 7:30 a m, to a maximum of 77 to 95 degrees F at 3:30 p m.

Results

T-1427 Derivatives:—The high level of resistance obtained in F_4, F_5 and F_6 selections from T-1427, compared to common *Lycopersicon esculentum*, is shown in Table I. Although these lines closely resemble *L. peruvianum* in many respects, several characters, such as slightly larger fruit size, very faint purple fruit striping, tendency in some cases for extremely severe cracking, and intermediate leaf size distinguish them from the wild parent. While certain *L. esculentum* genes have obviously been added, a most important character has been absent — they have been as incompatible with *L. esculentum* as was the original *L. peruvianum!*

TABLE I—TEST N-10: NEMATODE RESISTANCE OF SEEDLINGS OF T-1427 DERIVATIVES*

Line	Mother Plant	No Plants in Root Knot Classes				Resistant**	Susceptible†	Total
		0 None	1 Slight	2 Moderate	3 Severe			
Susceptible check‡	- -- ----	0	0	4	41	0	45	45
HES 2848	T-1427 F_5	30	1	0	0	30	1	31
HES 2947	T-1427 F_5	40	0	0	0	40	0	40
HES 2948	T-1427 F_6	40	0	0	0	40	0	40
HES 2949	T-1427 F_4	80	0	0	0	80	0	80

*Seeds planted August 18, 1947. Root knot readings made September 3, 1947. Root knot galls from Swiss Chard and onions used for inoculum

**Class 0 only.

†Classes 1, 2, 3.

‡In this test, as in many others, Pearl Harbor has been used as a check, or susceptible type. No appreciable difference in root knot susceptibility has been noted between commercial types of *Lycopersicum esculentum* in these studies.

4N Lycopersicon esculentum × 2N T-1427 selections:—Since none of the highly resistant T-1427 derivatives were compatible with *L. esculentum*, it was decided to double the chromosome number of *L. esculentum*, which facilitates hybridization of the two species. One hundred seeds of HES 3174, a fruitful Hawaii selection resistant to fusarium

wilt, spotted wilt and gray leaf spot, were placed on a filter pad in a petri dish with 5 cc of 0.8 per cent colchicine. Small additions of water were made from time to time to keep the volume at approximately 5 cc. After 10 days sprouted seeds were removed and planted in soil. A few plants which emerged early had been severely injured by the colchicine. Thirty seedlings were obtained, all but three of which, because of large, dark green, thick leaves, appeared to be 4N plants. Twelve of the most vigorous were transplanted to a tile bed, where they were grown to maturity. All were relatively non-fruitful, as was to be expected. Massed pollen, obtained by use of a small electric buzzer, was taken from 100 plants of T–1427 derivatives 2848, 2947, 2948, and 2949 (25 plants each) and applied to stigmas of the (apparent) 4N plants of 3174. Good fruit set was secured, but relatively few seeds were obtained. The larger ones were planted without drying, immediately after removal from ripe fruits, in volcanic black sand (cinders), and irrigated heavily with a cuprous oxide suspension. Of 19 plants obtained, 6 died with extreme chlorosis, while the remaining 13 were transplanted to a flat and then to gallon cans (one plant per can) along with 20 grams of tomato root knot galls. Plants were transferred to tile beds March 8, at which time 20 grams of inoculum was again added to the soil surrounding the roots of each plant. They were left in the beds for 4 months — until July, 1948 — and although their vigor was excellent and flowering very profuse, no fruits were set. Since promising material had been obtained from Watts, it was decided simply to dig the plants to determine their resistance to nematodes. Twelve Pearl Harbor plants, planted adjacent to the (apparent) triploids had become so badly galled that they had begun to die and were removed on May 15. All of the 4N × 2N plants were completely free of galls. While no breeding material was obtained, the test was of value in again demonstrating the high dominance of resistance to root knot contributed by the *L. peruvianum* gene or genes.

HES 3386 and 3386 × susceptible behavior:—Data in Table II, secured in three separate tests, show the high resistance of 3386 compared to susceptible lines. It is immediately seen, also, that the resistance has been highly dominant in the F_1 hybrid. It has been recognized that class 1 is the weak point in securing data on resistance. One is confronted with plants which may have only a hint of a root swelling, to plants with one or two small galls, to three, four, and so on, galls of varying size. As indicated in footnote[§] for Table II, many plants placed in class 1 have unquestionably been highly resistant at maturity. Occasionally, check plants will escape without any galling, as shown in tests N–14A and N–14B. In later tests, when plants have been given slightly longer growth periods before examination, and when heavier quantities of inoculum have generally been used, escapes have been less frequent. These early tests of 3386 were particularly encouraging because of the absence of any plants showing galling in classes 2 and 3, and the knowledge that 3386 was highly compatible with commercial type tomatoes.

From the cross, 3386 × susceptible, several F_3 selections were made. Data for the F_2 and for F_3 selections of obvious heterozygosity will

TABLE II—TESTS N-14A, N-14B, N-15: NEMATODE RESISTANCE OF SEEDLINGS OF SELECTION HES 3386 AND ITS F_1 HYBRID WITH SUSCEPTIBLES

Line	No. Plants in Root Knot Classes				Resistant†	Susceptible‡	Total
Test N-14A*	0	1	2	3	—	—	—
HES 3386	40	0	0	0	40	0	40
Susceptible check	2	13	7	17	2	37	39
3386 × susceptible F_1	36	1	0	0	36	1	37
Test N-14B**	—	—	—	—	—	—	—
HES 3386	54	0	0	0	54	0	54
Susceptible check	2	17	30	58	2	107	109
3386 × susceptible F_1	87	0	0	0	87	0	87
Test N-15***	—	—	—	—	—	—	—
HES 3386	122	11§	0	0	122	11§	133
Susceptible check	0	1	21	170	0	192	192
3386 × susceptible F_1	42	10	0	0	42	10	52

*Seeds planted January 9, 1948; root knot readings made February 4; root knot galls from tomatoes used for inoculum.

**Seeds planted January 21, 1948; root knot readings made February 22, root knot galls from pineapples used for inoculum.

***Seeds planted March 17, 1948; root knot readings made April 15; root knot galls from tomatoes used for inoculum.

†Class 0 only.

‡Classes 1, 2, 3.

§Six of these seedlings, in class 1, were planted adjacent to heavily knotted susceptible seedlings and allowed to grow to maturity Severe galling progressed on roots of susceptible plants, while no galls formed on roots of the six class 1 plants, even though root systems became entangled in the soil as plants grew. Thus many, if not all, of the class 1 plants of 3386 were highly resistant as mature plants. Six seedlings of 3386, in class 0, were planted in similar manner, and all remained free of galls.

not be presented here for, although within the lines under test no more than two major genes are apparently involved, there are modifiers or other factors, perhaps of additive action, in play which will require detailed study. Some excellent 3:1 fits have been obtained, yet such could be obtained in a two gene system, with one gene pair homozygous. Improvements in testing techniques may also help to clarify the inheritance picture, so that it is felt no useful purpose will be served by presenting detailed F_2 or F_3 data at this time.

Recovery of a high level of resistance in F_3 selections of 3386 × susceptible was not difficult. In fact, from only 12 plants selected for resistance in one F_2 test, four were highly resistant. Data on resistance of these four selections are presented in Tables III, IV, and V. In test N–18, all plants of the four selections were highly resistant in the seedling (Table III) and mature plant (Table IV) stages, whereas

TABLE III—TEST N-18: NEMATODE RESISTANCE OF SEEDLINGS OF CERTAIN F_3 PROGENY OF 3386 × SUSCEPTIBLE*

Line	No Plants in Root Knot Classes				Resistant**	Susceptible†	Total
	0	1	2	3			
Susceptible check	1	4	12	74	1	90	91
3962 F_3	55	0	0	0	55	0	55
3963 F_3	70	0	0	0	70	0	70
3999 F_3	45	0	0	0	45	0	45
4000 F_3	45	0	0	0	45	0	45

*Seeds planted December 3, 1948, root knot readings made December 24; root knot galls from tomatoes used for inoculum.

**Class 0 only.

†Classes 1, 2, 3.

susceptible check plants were, for the most part, heavily galled. It is of interest, however, that in test N–20, slight galling occurred in plants of 3962, 3963 and 3999. One plant of 3999 was placed in class 2. Complete agreement between the two tests was not, therefore, obtained except for resistance within the 4000 selection.

TABLE IV—TEST N-18: NEMATODE RESISTANCE OF FIELD GROWN MATURE PLANTS OF CERTAIN F_3 PROGENY OF 3386 × SUSCEPTIBLE*

Line	No. Plants in Root Knot Classes				Resistant†	Susceptible‡	Total
	0	1	2	3			
Susceptible check**	1	1	1	47	1	49	50
3962 F_3	12	1	1	0	12	2	14
3963 F_3	6	0	0	0	6	0	6
3999 F_3 . . .	7	0	0	0	7	0	7
4000 F_3	16	0	0	0	16	0	16

*See Table III for data on seedling reading; plants left in field until May 18; field was known to be heavily infested with nematodes.
**These checks were nematode-free plants transplanted to the field without addition of inoculum.
†Class 0 plants only
‡Class 1, 2, 3 plants.

Since these resistant lines were in general superior in horticultural characters to 3386, individual selections were made and tested. A few of the plants showing light galling in test N–20 were included as shown in Table VI (test N–24). The column headed "?" in these tables includes those plants which had root systems with the slightest indication of a root swelling. In previous tests these had been placed in class 0. Table VI reveals, again, a generally high level of resistance in lines 3962, 3963, 3999, and 4000, as compared to the check which in this test was extremely heavily galled. Yet, for the first time, plants of 4000 were observed to be lightly galled, and a few class 2 and 3 plants appeared in selections from 3962 and 3963. There was a tendency for less galling in line 4000 than for the other lines.

Selection 3962 (4267), as seen in Table VI, was placed in class 2 at time of selection. Resistance of the progeny was not on a level with most 3962 selections. Since seeds from these plants have been open

TABLE V—TEST N-20: NEMATODE RESISTANCE OF SEEDLINGS OF CERTAIN F_3 PROGENY OF 3386 × SUSCEPTIBLE*

Line	No. Plants in Root Knot Classes							?‡	Total	Resistant**	Susceptible†
	0	1				2	3				
		Number of Galls									
		1	2	3	4 or more						
Susceptible Check	0	0	0	0	1	21	71	0	93	0	93
3962 F_3. . .	22	0	1	0	0	0	0	0	23	23	0
3963 F_3.	36	1	2	1	1	0	0	1	42	40	1
3999 F_3	37	0	1	1	6	1	0	6	52	39	7
4000 F_3. .	25	0	0	0	0	0	0	1	26	25	0

*Seeds planted February 14, 1949; root knot readings made March 21; root knot galls from tomatoes used for inoculum.
**Class 0, and class 1 plants having 3 galls or less.
†Classes 2, 3, and class 1 having four or more galls; question marks disregarded.
‡Questionable indication of root swelling.

FIG. 1. Typical seedlings from nematode resistance test N-23. In the center, note galling of the susceptible check, typical of commercial varieties. Seedlings of 4000 (4245) on left, and 3962 (4270) on right, showed high resistance to gall formation. Both are highly compatible with *Lycopersicon esculentum*.

TABLE VI—TEST N-24: NEMATODE RESISTANCE OF SEEDLINGS OF F_4 PROGENY OF 3386 × SUSCEPTIBLE*

Line	Root Knot Reading Mother Plant	No. Plants in Root Knot Classes							?‡	Resistant**	Susceptible***
		0	1				2	3			
			Number of Galls								
			1	2	3	4 Or More					
3962 (4114)F_4 ..	0	35	9	4	3	3	0	0	8	51	3
3962 (4115)F ...	0	52	5	2	0	0	0	0	2	59	0
3962 (4267)F_4 ..	2	6	2	4	0	4	1	0	3	12	5
3962 (4268)F_4...	0	41	3	1	4	3	0	0	8	49	3
3962 (4269)F_4...	1	24	6	4	3	7	1	0	8	37	8
3962 (4270)F_4...	0	34	5	2	4	0	0	0	7	45	0
3962 (4272)F_4...	0	9	2	2	0	0	0	0	2	13	0
3962 (4273)F_4...	0	14	2	1	0	0	0	0	1	17	0
3962 (4282)†F_4...	0	38	5	4	0	4	1	2	8	47	7
4000 (4243) F_4 ..	0	24	2	2	3	0	0	0	3	31	0
4000 (4244)F_4 ..	0	27	6	2	0	0	0	0	4	35	0
4000 (4245)F_4...	0	33	8	3	2	1	0	0	8	46	1
4000 (4246)F_4...	0	41	6	0	0	0	0	0	4	47	0
4000 (4247)F_4...	0	31	3	2	0	0	0	0	6	36	0
4000 (4291)F_4...	0	20	2	3	0	1	0	0	3	25	1
3999 (4283)F_4..	2 small galls	40	4	3	0	1	0	0	7	47	1
3999 (4284)F_4...	0	38	4	3	4	1	0	0	5	49	1
Susceptible check	–	0	0	0	0	0	17	122	0	0	139

*See Tables IV and V for F_3 data; seeds planted June 1, 1949; root knot readings made June 28 root knot galls from tomatoes used as inoculum.
**Class 0, and class 1 plants having 3 galls or less.
***Classes 2, 3, and class 1 plants having 4 or more galls; question marks disregarded.
†Three class 0 plants massed.
‡Questionable indication of root swelling.

pollinated it is to be expected that some cross fertilization may have occurred. Such natural crossing is generally (not always) relatively low for the tomato, however, and can not explain the type of variation noted in Table VI. In known heterozygous populations, of resistant by susceptible crosses, the number of susceptible plants in classes 2 and 3 is typically far greater than for any selection shown in the table.

Further confirmation of the resistance of the most promising selections from 3962 and 4000 was secured in test N–23 (Table VII). In this test, light galling in class 1 was less prevalent in resistant lines than in test N–24. Also, there were relatively fewer severely galled plants in class 3 for the susceptible check. Yet, it will be noted that no escapes occurred among 117 check plants, while not one of 290 plants in resistant lines were classed as susceptible. High dominant resistance was again shown by the 25 F_1 plants tested.

Stem Swellings (Stem Knot) of Resistant and Susceptible Lines:— Appearance of swellings on stems of seedlings has been commonly observed, where seeds were planted over chopped-up root knot galls. Stem infection in this case presumably occurs before emergence of the stem above the soil. Casual observation of resistant as compared to susceptible lines indicated that there were more swellings on stems of susceptible plants than on resistant ones. Data were secured, therefore, on actual counts of plants showing this type of infestation. These data, in Table VIII, show considerably heavier "knobbing" of stems of susceptible plants. In test N–24, resistant plants were almost entirely free of such swellings, while, for some unexplained reason, a uniformly low amount of swelling in resistant lines occurred in test N–23. Since these data were secured from tests in which seeds were planted ½ to 1 inch above inoculum, it is possible that, by proper manipulation of placement of inoculum relative to seed, much heavier stem infestation could be secured and perhaps more significant variations would be found. If the association were to be found consistent and reliable, then the opportunity arises of using such readily observed differences

TABLE VII—TEST N-23: NEMATODE RESISTANCE OF SEEDLING TOMATOES*

Line	No. Plants in Root Knot Classes							?‡	Total	Resistant**	Susceptible†
	0	1: Number of Galls				2	3				
		1	2	3	4 Or More						
Susceptible check . . .	0	0	0	0	11	21	85	0	117	0	117
3962(4114) F_4 . .	66	3	0	0	0	0	0	7	76	69	0
3962(4115) F_4 . .	24	1	0	0	0	0	0	1	26	25	0
3962(4270) F_4. . . .	87	7	1	0	0	0	0	7	102	96	0
4000(4245) F_4. . .	35	0	0	1	0	0	0	2	38	36	0
4000(4247) F_4 . .	31	0	0	1	0	0	0	2	34	32	0
4000(4291) F_4	32	2	0	0	0	0	0	3	37	32	0
4000 ×susceptible F_1	8	0	0	0	0	0	0	0	8	8	0
3962 ×susceptible F_1	17	0	0	0	0	0	0	1	18	17	0

*Seeds planted June 6, 1949; root knot readings made July 5, 1949; root knot galls from tomatoes used for inoculum.

**Class 0, and class 1 plants having 3 galls or less.

†Classes 2, 3, and class 1 plants having 4 or more galls; question marks disregarded.

‡Questionable indication of root swelling.

TABLE VIII—TESTS N-23 AND N-24: PER CENT OF SEEDLING PLANTS SHOWING STEM SWELLINGS

Line	Resistance or Susceptibility	Test N-23*		Test N-24†	
		No. Plants Tested	Per Cent of Plants With Stem Swellings	No. Plants Tested	Per Cent of Plants With Swellings
Susceptible check	Susceptible	202	19.3	257	25.0
3962 (4114)	Resistant	252	2.8	53	0.0
3962 (4115)	Resistant	202	2.0	80	0.0
3962 (4270)	Resistant	239	2.1	50	0.0
4000 (4245)	Resistant	205	4.4	52	0.0
4000 (4247)	Resistant	154	4.5	46	0.0
4000 (4291)	Resistant	187	2.7	32	3.0

*Reading on plants showing stem swelling made 16 days after seeds were planted.
†Reading on plants showing stem swelling made 14 days after seeds were planted.

as a practical breeding procedure for early elimination of susceptible lines without the necessity of careful examination of roots.

Entrance of Nematodes Into Roots:—On April 13 roots from test N-15 seedlings of 3386 (resistant) and susceptible check plants which had received the root knot inoculum at time of planting seed were stained with acid fuchsin, using the technique described by McBeth, Taylor and Smith (8). Microscopic examination, made with the kind advice and assistance of Dr. M. B. Linford of the Pineapple Research Institute, revealed heavy infestation of roots of both the 3386 (resistant) and susceptible plants. However, in the 3386 line under the rather limited observations made, no large, well developed females were found, whereas, in the susceptible checks numerous well developed females were seen. Some cell necrosis in roots of resistant plants was observed, where nematodes were present, even though growth of the parasite was apparently limited. These observations showed that larvae enter readily into plants with 3386 type resistance, and that their development is checked; sufficient data were not secured, however, to determine definitely whether reproduction of *Heterodera marioni* is completely or only partially inhibited.

DISCUSSION

Since microscopic examination revealed the entrance of many larvae into roots of "resistant" plants it obviously follows that the term resistance as we have used it is not a resistance to nematode entrance but, rather, a resistance to gall formation, similar to that found by Barrons for several kinds of plants (2, 3). Apparently, the larvae, themselves, are rendered incapable of inducing galls or the plant in some other way is able to counteract gall induction. Complete freedom of all plants from galling, however, has not been found. Under the conditions of these Hawaii tests, most plants of resistant lines have been completely free of galls, with a small number of plants showing one or more small galls. Variations between tests have been appreciable and may be due to various factors such as: testing methods; errors in classification (with class 1 the pivotal problem); root decay organisms (reducing root area on which classification is based and re-

sulting also in loss of galls when seedlings are removed from the soil); variability of host plants; variability of the parasite; possible soil and climatic effects. Of these possible variables, the question of paramount importance is that of races or strains of the parasite. That such races exist is indicated by the work of Christie and Albin (4), Clayton (5), Mackie (7), and Steiner (11). The resistance of lines under study here has been demonstrated only against nematodes collected, in several locations on the island of Oahu, from pineapples, tomatoes, carrots, lettuce, onions and Swiss Chard. Whether the resistance is "universal" in character, or whether the parasite is capable of rapid — or ultimate — adaptation to the lines remains to be seen. Nor has it been demonstrated that resistance to root knot formation is a complete solution to the problem. Decay of root systems of root knot resistant lines has been common. What is the association between these decay organisms and entrance of the parasite into the tomato root, or entrance *and* gall formation? In many tests we have observed decided stunting and heavy loss (death) of seedlings of susceptible as compared to resistant lines caused directly or indirectly by nematodes or other organisms introduced with the inoculum. In other tests such differences, between resistant and susceptible lines, have not been noticeable.

Complete agreement between seedling resistance and mature plant resistance has not been obtained, which is in agreement with the result of Watts (12). The correlation is, however, high. Appearance of galls on mature plants which, as seedlings, were free of galling, may mean a change in resistance with age, possible chance escape from galling in the seedling tests, parasite variability or adaptability, or differing environmental influences during tests of seedlings and mature plants.

While the four lines, 3962, 3963, 3999, and 4000 have shown a consistently high level of resistance to root knot, line 4000 has appeared to be slightly more resistant as indicated by fewer galls on the roots. This line has been less vigorous than the others, with a less well developed root system. Since there were fewer roots on which galls might develop, is it possible that the chances for galling on any given plant were therefore less and that this escape factor would, therefore, be reflected in the data? It would indeed seem logical that the greater the root system on plants only very slightly susceptible to galling the greater may be the expected accuracy of reading, with fewer plants likely to appear in class 0.

Preliminary data have indicated that stems of susceptible plants are more readily knotted than those of resistant ones. This may mean that the unknown protective factor or factors responsible for resistance to gall formation in the root is systemic in nature and also protects the stem of young plants.

Recovery of apparent 3386 type resistance from 3386 × susceptible progeny has not been difficult. On the other hand, within other lines, selected or derived from Cr 46–8–2S, from Watts, individual plants selected for high resistance have shown continued segregation so that the material has finally been abandoned. We have no explanation for this behavior. It does indicate that it will be wise to select carefully

from segregating progeny of each backcross to be sure that a high level of resistance is retained, rather than to depend entirely upon immediate backcrossing to rapidly attain commercial characters. Since we are not sure of the inheritance picture, both plans will be followed.

Linkage of adverse-type wild genes with 3386 resistance is possible, since it has generally been true that the most promising commercial type selections have not had the "homozygous" type resistance of 3386 or 4000. Yet selections 3962, 3963, 3999 and 4000 are essentially *Lycopersicon esculentum* in most characteristics, and some fruits are 2 inches or more in diameter, so that the chances for securing desirable commercial types appear to be excellent. The high dominance of resistance to root knot opens up the possibility of commercial use of F_1 hybrids carrying such resistance prior to final release of homozygous commercial varieties.

Summary

Continued selection for nematode resistance from progeny of a cross made in Hawaii involving *Lycopersicon peruvianum* as one parent resulted in isolation of lines highly resistant to root knot; they were, however, incompatible with *L. esculentum*. In the F_1 hybrid between these 2N lines and 4N *L. esculentum*, high dominance of resistance was demonstrated.

A selection, 3386, derived from the nematode resistant cross made by Smith and further tested and hybridized by Watts, was found to possess essential homozygous resistance to root knot in Hawaii. After further hybridization with *Lycopersicon esculentum*, four lines, 3962, 3963, 3999 and 4000, possessing a high level of resistance and improved horticultural characters, were obtained. Further hybridization for commercial characters will likely be required, however.

The 3386 type resistance is apparently not a resistance to entrance of larvae of *Heterodera marioni* but a resistance to root knot formation. Slight galling occurred in a small percentage of plants, with most plants free of galls. The lines are highly compatible with *Lycopersicon esculentum*.

A high correlation between seedling resistance and mature plant resistance was found to be characteristic of the lines.

Preliminary data on stem swelling (knotting or knobbing) of young seedlings indicated the possibility of a close association between stem and root resistance. Thus, resistance may not be confined to the roots alone.

High dominance of resistance may make possible early use of F_1 hybrids for commercial planting.

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Rates of Natural Cross-Pollination of Tomatoes in Various Localities in California as Measured by the Fruits and Seeds Set on Male-Sterile Plants[1]

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RECENT investigations in California have established that the rates of natural cross-pollination of tomatoes are influenced by at least three major factors. One of these — the distance between the flower that is the source of pollen and the one that receives the pollen — has been analyzed in tests of several arrangements of fertile and male-sterile plants (7). The importance of another factor — the abundance and activity of insect vectors — has been tested by comparing fruit and seed yields of plots of male-sterile tomatoes planted in different localities and is the substance of this report. A third factor — the comparative efficiency of different tomato varieties as sources of pollen and as pistillate parents — is being investigated in experiments now in progress.

PREVIOUS STUDIES

The rates of natural cross-pollination (hereafter abbreviated NCP) have been tested in the following eight stations known to the writer: Japan (3), Davis, California (7), Riverside, California (4), Connecticut (2), Minnesota and South Carolina (1), Pennsylvania (5), and Texas (9). None of these results are strictly comparable because different varieties that might conceivably differ in their attractiveness to insect vectors were used and because they also differed in planting designs and planting distances, which are known to affect rates of NCP. They differ in a further respect that male-sterile plants were used to measure NCP in one of these tests, whereas rates in the others were tested by using fertile plants as staminate and pistillate parents and by observing the proportion of hybrid seedlings in their progeny. Rates based on the use of male-sterile plants might be expected to be higher because, in contrast to fertile plants, they produce no pollen to compete with that which is carried to them by the vectors. Despite these potential sources of error and despite the many different localities tested, the reports agree to a remarkable extent, all rates falling between ½ and 4 per cent.

Only in the work of Currence and Jenkins (1) were comparable conditions maintained so that a valid comparison could be drawn be-

[1]This work was completed during tenure of a John Simon Guggenheim Memorial Fellowship.

These experiments requiring constant attention to plants in widely separated localities could not have been completed without the willing help of many workers. Much credit is therefore due the people listed in Table I, who generously offered the use of their land and who carefully tended the plantings. It is a pleasure also to acknowledge much aid from the following people. Bernarr Hall, Asst. Farm Advisor in San Diego County and Warren Norton, Farm Advisor in Yolo County helped to enlist the aid of farmers in their respective counties. Martha O. Rick, Jeanette Robinson, Flora Salaverria, and Robert K. Soost helped in scoring the records. P. H. Timberlake, Associate Entomologist of the Citrus Experiment Station, Riverside, California, kindly identified the species of bees.

tween the rates of NCP in two widely separated localities. The rates ascertained at Charleston, South Carolina, and St. Paul, Minnesota were found to be quite similar, those for Charleston being slightly lower.

The evidence in the literature therefore gave little encouragement to a search for large differences in rates in new localities. Nevertheless, the various sections where tomatoes can be grown in California differ so greatly in their ecology, and the measurement of NCP is so simplified by the use of male-sterile plants, that it was decided to make these exploratory tests. The effort was well rewarded, for differences of unexpected order were encountered.

Location of Plots

Special interest is naturally attached to any locality in which rates of NCP are high, since insect vectors might be utilized in combination with male-sterile plants to produce hybrid seed without the necessity of hand-pollination. Accordingly, certain plots were planted close to large expanses of undisturbed ground and also close to constant and exposed sources of water, sites that entomologists say are most likely to be frequented by solitary bees, species of which are most responsible for cross-pollinating tomatoes in California. Other plots were planted at greater distances from such sites for purposes of comparison.

The location of the test plots and other pertinent information concerning them is given in Table I. An attempt was made to place plots in exactly the same site in successive years, but this was possible finally in only two instances (454-473; 463-475). In each of two other pairs of plantings (455-463; 456-471) the sites of the plots were not more than 100 yards apart and were very similar in their ecology. In the plantings made at Capay in 1946 (461 and 462) and at Davis in 1947 (475, 476, and 477) several plots were planted at greater distances and in somewhat different ecological situations in various sites within one large field. Other information concerning the sites will be mentioned in discussing the results.

Use of insecticides was restricted to the least necessary to control hornworms and various species of fruit worms. No data available indicate how much these insecticides might have reduced the activity of tomato pollen vectors

Design of Plots

In the preliminary tests of 1945 Design A (Fig. 1) was used. The unsymmetrical arrangement of sterile and fertile plants in this design served to test exploratorily the difference in rates of NCP expected of sterile plants completely surrounded by fertile plants and of sterile plants in solid rows flanked by rows of fertile plants. But in 1946 and 1947 this arrangement was replaced by Design B (Fig. 1) because the latter was found in the meantime (7) to be more efficient, and also because a design was needed in which sterile and fertile plants were arranged uniformly throughout. Rates observed in the plots of the two designs are not strictly comparable because the rates of NCP of sterile

TABLE I—LOCATION AND IMPORTANT FEATURES OF TEST PLOTS USED TO MEASURE NATURAL CROSS-POLLINATION

Plot No.	Year	Design	Location	Cooperator	Surroundings	Distance From Undisturbed Land	Growth*
451	1945	A	Santa Paula Ventura Co.	Mr Alson Condit W. Atlee Burpee Co.	In center of large agricultural area	At least 1 mile	Fair; number of testable plants reduced by spotted-wilt
452	1945	A	Westminster Orange Co.	Mr. E L. Abernethy Haven Seed Co.	In mixed agricultural and residential area	About ½ mile	Excellent
453	1945	A	Riverside Riverside Co	Dr. J W. Lesley Citrus Experiment Station	In young citrus grove	About 1 mile	Good, slight nematode infection
454	1945	A	Bonita San Diego Co.	Mr. Ray Koenig	In newly planted orchard on hillside	50 yards	Good
455	1945	A	Davis Yolo Co.	Agricultural Experiment Station	In center of large agricultural area	400 yards	Excellent
456	1945	A	Capay Yolo Co.	Mr. Louis Janelos	In newly planted almond orchard	25 feet	Many plants lost, growth of survivors fair
461	1946	B	Capay Yolo Co.	Mrs. Katherine Kustoris	In vacant fallow area	300 yards	Fair; midseason growth slow
462	1946	B	Capay Yolo Co.	Mr. Gus Woupius	In same vacant fallow area as 461	50 yards	Good
463	1946	B	Davis Yolo Co.	Agricultural Experiment Station	Close to site of 455	400 yards	Excellent
471	1947	B	Capay Yolo Co.	Mr. Herger	Vacant lot in residential area near site of 456	40 feet	Variable, records taken only from west end where growth was good
472	1947	B	Riverside Riverside Co	Dr. J. W. Lesley Citrus Expt. Sta.	In newly planted peach orchard close to site of 453	About 1 mile	Poor; many plants diseased
473	1947	B	Bonita San Diego Co.	Mr. Ray Koenig	Same site as 454	50 yards	Fair; many plants lost
474	1947	B	Oceanside San Diego Co.	Mr. Ray Steckle	On sandy ocean bluff	About 700 yards	Excellent
475	1947	B	Davis Yolo Co.	Agricultural Experiment Station	Same site as 463	400 yards	Excellent
476	1947	B	Davis Yolo Co.	Agricultural Experiment Station	Same field as 463 and 475 but different position	200 yards	Excellent
477	1947	B	Davis Yolo Co.	Agricultural Experiment Station	Same field as 463 and 475 but different position	50 feet	Good; growth less vigorous than in 475 and 476

*Wherever growth is described as 'excellent" branches of adjacent plants intermingled to such an extent that they completely covered the ground. The remark "good" indicates intermingling of branches of about half the adjacent plants.

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F F F F F F F
F S F S S S S
F F F F F F F
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DESIGN A

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  F   F   F   F
F S F S F S F S F
  F S F S F S F S F
    F   F   F   F
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DESIGN B

FIG. 1. Diagram of planting designs. Design A used in 1945. Design B used in 1946 and 1947. F represents a fertile plant; S represents a male-sterile plant.

plants arranged as in Design B are known to be higher than those of sterile plants only partly surrounded by fertile plants as in Design A, but the differences expected of such changes in design are of a much smaller order than those observed between many of the test plots in this experiment (7). In all plots the plants were placed 4½ to 5 feet apart in rows spaced similar distances.

MUTANTS USED

The variety San Marzano was used exclusively for these tests because it grows better under the widely differing conditions of the selected localities than any other indeterminate variety of which male-sterile mutants were available. Determinate varieties such as Pearson had previously (7) been found unsatisfactory for the asexual propagation sometimes needed for propagation of the male-sterile plants.

The male-sterile mutant ms_3 described elsewhere (6) was used in the plantings of 1945. For subsequent tests it was replaced by the mutant ms_9 (8) because the male-sterile segregates of the latter have no macroscopically visible remnants of microspores that might be mistaken for fertile pollen, as might conceivably happen in those of the former, and are therefore identified in the field with greater reliability. Both mutants agree in the nearly normal size and form of their anthers — a factor that seems to exert considerable influence on the rates of NCP. It is necessary to use mutants with the least modification of anther form in order to realize the highest rates of NCP (8). Since the rates of NCP of the two mutants do not differ significantly, the results of the tests made with the two are comparable.

A necessary precaution in these experiments is to determine whether the male-sterile mutant, in the range of variation of environmental conditions in the field, can ever produce functional pollen, self-pollinate itself, and thus give a false notion of the rate of NCP. In a previous test (7) it was found that the mutant ms_2 (of the variety Pearson) was dependable, yielding no seeds whatever when planted in complete isolation. A similar test was made here with ms_9, 11 plants being located in 1947 in isolation of at least 1,000 yards from any other tomatoes. The plants did not grow vigorously, but flowered profusely during the season of greatest vector activity. They produced a total of 5,911 flowers according to the number of pedicels counted at the end of the season. Of a total of 11 fruits produced, 10 were parthenocarpic

and 1 contained a single seed. It is possible that the isolation distance was not sufficient to prevent completely the visits of stray insects, or that it is within the limits of variation for a few male gametophytes of this mutant to develop into normal pollen grains (although this has never been observed microscopically). If the latter were true, it must be a very rare phenomenon according to the rates observed and could not affect the observed levels of fruit and seed set to any significant extent. Similar tests were not made with the ms_3 mutant, but production of normal pollen has likewise never been observed in this mutant.

Methods of Measurement

The fruit and seed yields and the fraction of flowers that yielded fruit were recorded as in the previous experiment (*7*). Only two points require comment.

First, a complete seed count of the tested plants, especially of the fertile ones, requires too much time to be feasible. Instead, for the fertile plants, the total seed production was estimated with reasonable accuracy from the total seed count of samples — usually samples of fruits representing 10 per cent of the total weight and containing fruits of representative sizes; for the sterile plants seeds were counted from all fruits, or from samples of 50 or 25 per cent.

The second point deals with the estimates of percentages of flowers that set fruit. As described previously, these percentages are derived from counts of pedicels of flowers that have yielded fruits and of those that have failed to do so. Pedicels were examined throughout the length of four branches taken at random from each plant. In this way the fruit-setting performance of the plant is conveniently recorded for all parts of the season. The method does not, however, give an accurate mean for the whole period of flowering. The defect lies in the fact that, as it grows, the plant expands radially in all directions, and, for simple geometric reasons, flower production increases with the square of the radius. Now, since the sample is taken from a branch, which roughly approximates a radial line, the sample includes too many flowers from the center of the plant and too few from the periphery to contain a proportional representation of flowers from all parts of the plant. Least error is incurred midway along the branches where, fortunately, the highest rates of NCP are observed (Figs. 2 and 3). Despite this objection, the values of different plots are nearly comparable because the same method of sampling was used throughout.

The geometric objection could be satisfied by sampling sectors of the plant instead of radial branches, but the reliability of this method is questionable because fruits may not be equally distributed over the plant. For reasons still the secrets of the vectors themselves, fruits are often oddly concentrated on one side or another of the sterile plants. Perhaps the only entirely satisfactory method of measurement is to sample every inflorescence of the plant.

The measures of fruit and seed yield were made of all surviving sterile plants and of five or six representative fertile ones. Determining the representative fertile plant constitutes another problem peculiar to these experiments. Fertile plants from the inner rows of Design B

are subject to crowding by the aggressive sterile plants, and their yields might thereby be reduced. Those from the outer rows, however, suffer practically no competition and are consequently apt to give a higher yield than plants of the same variety growing under the same conditions except in normal competition with other fertile plants in solid plantings. Yields of fertile plants growing together in a nearby solid block might be taken as the best control figures, but the usefulness of these figures could be doubted on the grounds that the soil and other environmental factors might differ between the location of the test plot and that of the control plot unless plantings were replicated extensively. In all test plots it was decided arbitrarily to measure yields of fertile plants, half of which were in the inner rows and half in the outer rows.

Presentation of Results

The observations are presented in condensed form in Table II. Fruit yields are stated in terms of mean production per plant. Seed yields are given in terms of mean per plant and also in terms of mean per fruit. The per cent of flowers that set fruit is the measure previously explained. The final column for each measure, representing a comparison of the yields of fertile and sterile plants, is the sterile-plant yield expressed as a percentage of the fertile-plant yield. This percentage was adopted on the basis of the following argument.

The interest in this experiment centers on the yields of the male-sterile plants, but the yields of these alone are relatively meaningless without some sort of control or standard of comparison. If, for instance, the growing conditions do not permit normal fertile plants to set fruit and produce seed abundantly, then a low yield on sterile plants does not necessarily imply low rates of cross-pollination. To what extent the physiology of the two types of plants is similar enough to permit such comparisons is not known. Certainly it should suffice for rough comparisons. It is apt to be least reliable in ratios of total fruits and total seeds per plant because the total number of flowers per plant, one factor on which total fruit and seed yields depend, may be much greater in sterile than in fertile plants (Table II). The numbers of flowers per plant presented in Table II were not actually counted, but were calculated from the quotient of the number of fruits per plant and the proportion of flowers that set fruit. This method admittedly is subject to considerable error and the estimates thereby obtained must be evaluated accordingly.

Many more test plots were planted than recorded in this report. A high percentage of casualties in this type of experiment is unavoidable. With the exception of a few plots of poor growth, the yields are reported only for plots of good growth.

The record is so deficient in plots planted in the same site in successive years that a comprehensive statistical analysis of all plots is not justified.

Interplot Variation

The total seed yield of sterile plants expressed as a proportion of the fertile-plant yield varies from 1.9 to 47 per cent (Table II). This

TABLE II—YIELDS OF FLOWERS, FRUITS, AND SEED OBSERVED IN FERTILE AND MALE-STERILE PLANTS, WITH COEFFICIENTS OF VARIABILITY IN CERTAIN CASES FOR SEEDS PER PLANT AND PER CENT FLOWERS THAT SET FRUIT

Plot No.	Location	Seeds Per Plant					Seeds Per Fruit			Flowers Per Plant**		Fruits Per Plant			Per Cent Flowers That Set Fruit				
		Sterile		Fertile		Per Cent St/Pt*	Sterile	Fertile	Per Cent St/Pt*	Sterile	Fertile	Sterile	Fertile	Per Cent St/Pt*	Sterile		Fertile		Per Cent St/Pt*
		No.	Cv (Per Cent)	No.	Cv (Per Cent)										Per Cent	Cv (Per Cent)	Per Cent	Cv (Per Cent)	
451	Santa Paula	—	—	—	—	—	9.3	76.5	12	—	—	—	—	—	6.6	—	83.0	—	8.0
452	Westminster	362	—	8,390	—	4.3	8.9	33.6	26	890	420	49	256	19.0	5.5	—	60.9	—	9.0
453	Riverside	434	—	11,600	—	3.8	12.5	48.5	26	1,000	420	33	232	14.0	3.3	—	55.6	—	5.9
454	Bonita	618	—	16,800	—	3.7	8.3	33.0	25	1,790	820	70	500	14.0	3.9	—	61.1	—	6.4
455	Davis	995	—	10,700	—	9.3	14.3	29.7	48	620	1,280	69	360	19.0	11.1	—	27.8	—	40.0
456	Capay	2,130	—	7,770	—	27.0	17.0	34.5	49	420	480	126	224	56.0	30.3	—	46.3	—	65.0
461	Capay	687	31	5,250	23	13.0	15.7	34.5	45	490	300	43	152	28.0	8.8	28	50.9	14	16.0
462	Capay	4,260	37	9,160	24	47.0	21.5	44.1	49	1,680	490	198	219	90.0	11.8	35	45.0	8	26.0
463	Davis	2,410	54	10,200	39	24.0	23.3	50.2	46	1,540	520	103	203	51.0	6.7	33	38.8	26	17.0
471	Capay	3,060	—	8,050	—	38.0	26.7	40.9	65	420	390	114	197	58.0	26.3	—	51.5	—	53.0
472	Riverside	105	—	4,710	—	2.2	13.1	39.2	33	190	510	8	120	6.7	4.3	—	23.7	—	18.0
473	Bonita	699	—	5,890	—	12.0	7.7	62.0	12	740	135	90	95	95.0	12.1	—	70.1	—	17.0
474	Oceanside	2,560	36	15,600	30	16.0	15.9	76.0	21	1,260	300	161	205	79.0	12.9	15	64.7	10	19.0
475	Davis	652	35	15,900	20	4.1	13.3	48.2	28	1,140	680	50	329	15.0	4.3	30	48.6	23	9.0
476	Davis	722	32	12,100	32	5.9	14.4	41.8	34	1,060	570	49	290	17.0	4.2	25	47.6	5	9.1
477	Davis	240	52	12,900	26	1.9	17.4	44.0	40	450	720	14	293	4.8	3.1	35	39.5	18	7.7

*Per cent St/Pt represents the sterile-plant yield expressed as a percentage of the fertile-plant yield.
**Flowers per plant not counted but estimated from the quotient of "fruits per plant" and "per cent of flowers that set fruit".

twenty-fold difference is of an entirely unexpected order, lacking any counterpart in the literature, and leaves little doubt that many of the differences in yields between plots are statistically highly significant. In the sites of plots 456 and 471 consistently high yields were realized, the sterile plants producing a mean of more than 2,000 hybrid seeds apiece. The highest seed yield of any plot, 4,260 seeds per plant, was harvested from plot 462 in the same locality as plots 456 and 471, but in a somewhat different ecological site.

The proportion of flowers that set fruit, probably the best single measure of rates of NCP for reasons to be explained, is also extremely variable. The values fluctuate from 3.1 to 30.3 per cent and expressed as percentages of the fertile-plant yields, from 5.9 to 65 per cent.

The mean number of flowers per male-sterile plant, calculated as explained previously, shows surprising variability between plots. The number ranges from 190 to 1,790 and is much more variable and generally higher in sterile plants than in fertile ones.

The number of seeds per fruit displays much less variability, the plot means varying from 7.7 to 26.7, and in terms of fertile-plant yields, from 12 to 65 per cent.

The interest that is naturally attached to the great differences in yields of hybrid seed demands for practical reasons whether such differences between localities are sustained from one year to another. The answer is not entirely positive nor entirely negative. For such localities as Davis (plots 463 and 475) and Bonita (plots 454 and 473) the total seed yields from plots in identical locations in two different years differ very significantly. Marked differences are also noted in the per cent flowers that set fruit. In general it might be said that 1947 was a year of low vector activity at Davis and at the same time a year of higher activity in the localities tested in southern California.

The yields of the Capay plots are of special interest in this connection. Plots 456 and 471 were both surrounded by fallow soil and located within 40 feet of a large irrigation canal, on the other side of which rises an undisturbed slope inhabited by wild grasses and scattered live oaks. The relatively very high total seed yields and proportion of flowers that set fruit suggest that within the very similar ecological situation of these plots vector activity tends to be consistantly high from one year to another.

It was impossible to locate a plot in the same ecological situation at Capay in 1946, but the two plots that were planted in that year hint as to the ecological requirements of high vector activity. Plots 461 and 462 were planted in the same locality except that 462 was situated 150 feet from the canal and 461 about 900 feet from it. Plot 462 shows a very high seed yield — the highest, in fact, for sterile plants in any of the plots — but this yield is not matched by a correspondingly high fruit-setting capacity of flowers. It resulted from a tremendous growth of the sterile plants with consequent large yield of flowers, which, in spite of the small fruit-setting fraction, still produced nearly half as much seed as the fertile plants. The yields of plot 461 are much lower. The observations of all plots in the Capay region are therefore in keep-

ing with the hypothesis that the rate of NCP varies inversely with the distance from undisturbed land and constant source of water.

In 1947 a similar attempt was made to test the NCP rates in microecological terms at Davis. The three plots of this series were separated widely in a square field of approximately 40 acre area. All the plots were at least 800 feet from a constant and exposed source of water, but the distance from undisturbed land varied greatly, plot 477 being 50 feet away, plot 476 about 600 feet away, and plot 475 about 1,200 feet away. Plots 475 and 476 show a generally higher yield and rate of NCP than 477. Inasmuch as distance from large tracts of undisturbed land is concerned, therefore, the trend here is in the opposite direction from that suggested in the Capay series. The observations in southern California generally bear out the experience at Davis, since the yields and rates do not vary consistently in any manner with respect to distance from undisturbed land. Although these limited observations cannot be accepted as conclusive, proximity to constant sources of open water seems to be a more important factor governing the abundance of tomato pollen vectors. It would not be wise, on the other hand, to disregard completely the distance of plantings from undisturbed land, for the solitary bees responsible for pollination require such areas for nesting sites.

The great range of variation in yields of plots in different localities, and even within localities, emphasizes the necessity of sampling many plots of small size. Much more useful information is to be gained from a large number of plots of small size than from fewer plots of larger

Effect of Adjacent Plantings of Tomatoes

No consistent relationship was found between the proximity of large plantings of tomatoes and the observed levels of NCP. Although the experiment was not designed to test this effect, the plantings at Davis afford an opportunity for comparison. Plots 463 and 475 were planted in the midst of much larger plantings of the same variety, whereas the other plots at Davis were isolated by considerable distances from other plantings of tomatoes. In this series of plots the proximity of larger plantings does not appear to increase or decrease markedly the seed yields or rates of NCP. At least, these observations do not suggest that smaller plantings tend to attract a greater concentration of vectors and offer no reason to discourage the large-scale planting of fertile and male-sterile tomatoes for the production of hybrid seed.

Interplant Variation

It is interesting in this sort of exploratory experiment to assay the level of variability of yields between plants. For this purpose coefficients of variability were calculated for the total seed yields and the percentage of flowers that set fruit. Total seed yield was selected because it is the measure of greatest practical interest, even though it is apt to be the most variable one on account of the independent variation of many contributing factors. The fraction of flowers that set fruit was included since it is probably the best single measure of

NCP. In Design A used in 1945 the sterile plants differ in the arrangement of fertile and sterile plants surrounding them. Since this variability in arrangement might well increase the variability in the rate of NCP, coefficients were not calculated for the data of that year. Calculations were also omitted for other plots in which the number of either sterile or fertile plants measured was too small to afford a satisfactory measurement of standard deviation.

For total seed yield the coefficients (Table II) are very high. What is even more striking, however, is the fact that in all plots the values for sterile plants are higher than, or as high as, those of the fertile plants. The mean coefficient for total seed yield of sterile plants in all plots for which the statistic was calculated is 39.6 per cent, while that for fertile plants is 26.3 per cent. The difference is not so great as that previously observed (*7*) (47.1 per cent for sterile plants and 29.9 per cent for fertile ones), but the latter experiment was limited to a single planting.

A comparison between fertile and sterile plants of the coefficients of variability of the fraction of flowers that set fruit is of questionable validity because the low numbers of fruits counted probably adds a substantially large sampling variability to the inherent variability of the sterile plants. The values calculated for sterile plants are therefore very likely maximum estimates of variability; hence they can be compared safely with higher values. The coefficient for proportion of flowers that set fruit in sterile plants (with a mean of 28.7 per cent) is well below that for total seed set (with a mean of 39.6 per cent) in every plot. The former therefore is subject to less interplant variation and is a more efficient measure of NCP.

The high variability in yields of male-sterile plants, for which there is now abundant evidence, must be explained by preferences of the vectors for plants in certain positions. The reasons for, or even the characteristics of, these preferences are still little understood.

Comparison of Measures

The measures that should be adopted for comparisons in such investigations will obviously depend on the information sought. At this point it is necessary to differentiate between seed yield of sterile plants and various contributing factors, including the rate of NCP. It is obvious that the total number of flowers per plant, the proportion of flowers that set fruit, and the seed-producing capacity of the fruits are important factors conditioning total seed yield. Since the rate of NCP is fundamentally the proportion of the offspring that result from outcrossing, it is independent of the number of flowers produced by the plant, which factor can, rather, should be disregarded in any theoretical consideration of rates of NCP. The same recommendation can be extended to surveys in which the information sought is the potential amount of contamination from cross-pollination that might be expected under a given set of conditions. In previous studies of NCP reported in the literature, the customary plan has been to use fertile plants as pistillate and staminate parents, and the rate of NCP is determined as a function of the proportion of hybrid seedlings in the open-pollin-

ated progeny of the pistillate parent. Hence the very nature of the method employed takes no account of the numbers of flowers produced per plant.

The factor of flower number is therefore peculiar to the use of male-sterile plants, a fact amply illustrated by the present tests, in which the various plots differ to a very great extent in the number of flowers per male-sterile plant as already explained. A very high flower number (as in plots 462 and 463) can actually obscure a relatively low rate of NCP. The importance of this fact was not appreciated in the previous experiment (7) because all data were taken from one large plot in which growing conditions, and consequently, flower production were rather uniform.

For the purpose of measuring NCP, therefore, the best measures are either the proportion of flowers that set fruit or the product of this factor and the mean number of seeds per fruit.

For the practical purpose of manipulating fertile and male-sterile tomatoes for the highest production of hybrid seed, interest is naturally focused on total seed counts; in this respect total flower number cannot be disregarded. For highest yields of hybrid seed, a basically high rate of NCP must be coupled with a high flower production.

The data provide an opportunity to test the effectiveness of each measure alone as an indicator of total seed yield. None of the factors measured or calculated, except number of fruits per plant, is closely correlated with total seed yield. This lack of correlation might be explained partly by the independent variation of the contributing factors and partly by the heterogeneity of vectors and their habits. Thus while a certain mean number of seeds per flower visited might be expected of one species of pollen vector, it might not hold for another; consequently, if a basic correlation should exist, say between total seeds and proportion of flowers that set fruit, it would thereby be obscured. The high correlation between total fruit number and total seed number is of doubtful value where accurate estimates of hybrid seed production are needed since relatively little work is required in sampling seed number.

Observations of Insect Vectors and Seasonal Variation in Their Activity

Circumstances permitted the collection of the responsible pollen vectors and direct observations of their habits at Davis, Capay, and Riverside. One species of solitary bee, *Anthophora urbana* Cressm. was observed at all three stations. Without doubt this is the most abundant and most active vector at Davis, where it is seen frequently throughout the pollination period, but tends to be most numerous in late July. *Agapostemon Cockerelli* Crawf. is seen later in the season at Davis and at that time may assume a more important role than the other species. Smaller species of solitary bees have occasionally been seen visiting tomato flowers at Davis, but they are comparatively passive and their effectiveness in transmitting tomato pollen is doubtful. At Capay observations were too limited to assess the importance of the various species. Here *Anthophora urbana* is important, but

other smaller species, notably those of the genus *Halictus* were also caught in the act of visiting tomato flowers. At Riverside what appears to be the most frequent visitor is not a solitary bee, but, instead, a bumble bee, *Bombus sonorus* Say, which has been seen swarming around the plants, especially those of the green-fruited species. Here it is possible that *Anthophora urbana* plays a less important role.

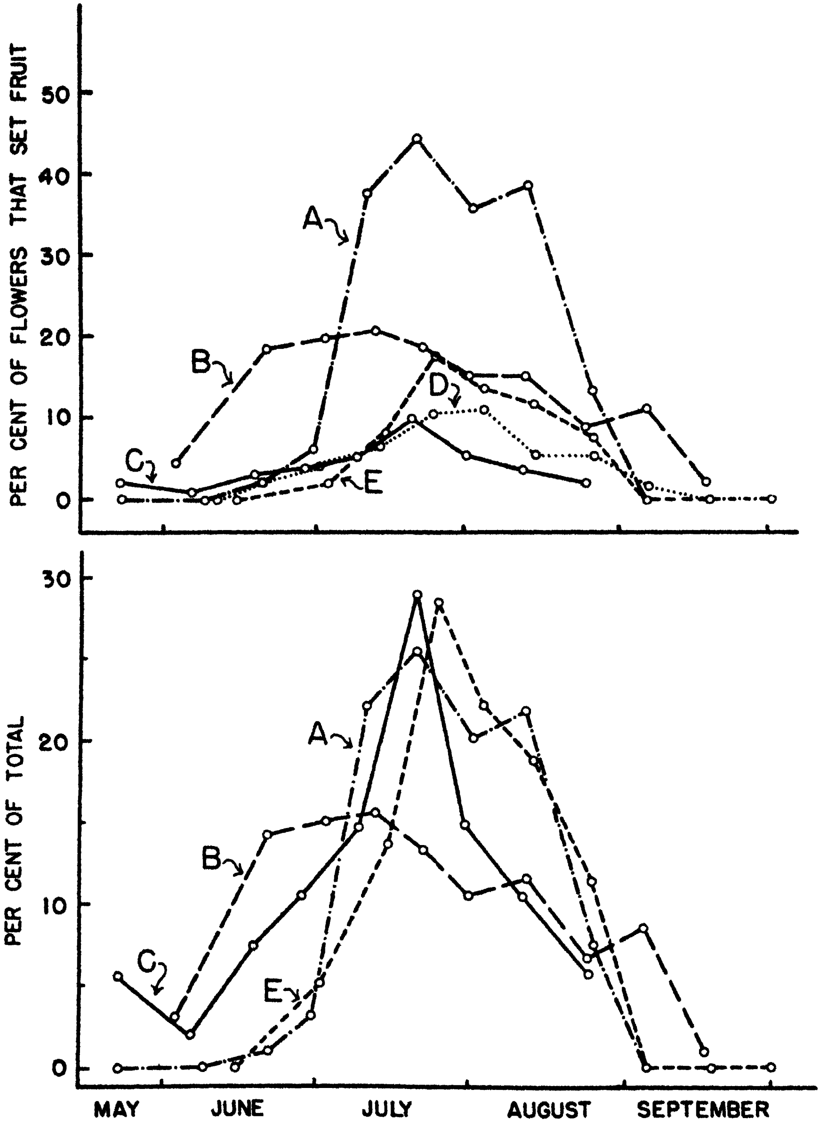
Further pertinent information concerning the seasonal activity of the vectors is provided by the records of percentage of flowers that set fruit. The records of several representative plots are summarized graphically in Figs. 2 and 3. In the plantings at Davis inflorescences were tagged at various times during the flowering season, and it was possible by reference to these tags at the end of the season, when pedicels of the entire branches were examined, to derive an accurate picture of the seasonal variation in NCP. For the other localities no date tags were placed, but the order of flowering was always evident in the sequence of inflorescences along a given branch. The rate of flower production was estimated from the behavior of plants at Davis and other localities, and the curves thereby obtained. Considering the potential inaccuracies of this method, the location of points in all graphs save those for Davis might be subject to as much error in time (abscissae) as 10 days. In their general shape, however, these curves should represent the relative activity of tomato pollen vectors in different parts of the flowering season.

The fruit-setting record of fertile plants in these plots differs in many respects from that of the sterile plants. The levels for fertile plants are much higher and are maintained at generally high levels for much longer periods of time than those of the sterile plants. Furthermore, the fertile-plant modes are more numerous and appear at different times, according to climatic conditions and possibly other factors. It seems likely, therefore, that the fruit-setting performance of the two types is governed by different factors and that the seasonal set of sterile plants is seldom limited by factors other than activity of the insect pollen vectors.

In Fig. 2 the absolute level of per cent of flowers that set fruit is depicted. The differences between plots in rates of NCP are so great, however, that comparisons of the shape of curves representing the different plots are somewhat obscured. If the total value of all points on each curve is arbitrarily set at 100 per cent, and the levels of points are thereby represented as percentages, as in Fig. 3, the differences in absolute rates are eliminated and seasonal comparisons facilitated.

All curves agree in their rise at midseason and in the reduction in levels at either end of the season. The agreement is even more remarkable in the coincidence of maxima in the mid to late July period of all curves. The rise to a maximum rate of NCP and the subsequent fall are abrupt in all curves except the one representing Oceanside.

A comparison of seasonal levels, clearer in Fig. 3 than in Fig. 2, reveals that at Davis and Capay the vectors are absent or inactive at the beginning and end of the season, whereas they suddenly reach a peak of activity in July and later become less active, the rate of declining activity being less than the rate of increasing activity. Fig. 2



FIGS. 2. and 3. Graphs representing seasonal fruit set on male-sterile tomatoes as a result of natural cross-pollination. Fig. 2 (above). Absolute levels of per cent of flowers that set fruit. Fig. 3 (below). Values adjusted so that total of all points of each curve equal 100 per cent. (A) Plot No. 471 Capay, 1947. (B) Plot No. 474 Oceanside, 1947. (C) Plot No. 453 Riverside, 1945. (D) Plot No. 455 Davis, 1945. (E) Plot No. 463 Davis, 1946.

and the data in Table II show, however, that, despite the similarity in shape of curves for the two localities, the rates at Capay are much higher than those at Davis. These similarities in quality, but differences in quantity of rates suggest that the same species of vectors are responsible in the two localities, but that they are much more abundant at Capay than at Davis. Direct observation substantiates the first assumption, but many more collections would be needed to test the second.

Riverside and Oceanside, the two localities in southern California represented in the graphs, differ from the others in never quite reaching the zero level of NCP at any period of the flowering season, although the season starts and ends at a lower level than it reaches in midseason. The coincidence of the abrupt maximum of the Riverside curve with that of Davis and Capay (Fig. 3) might be attributed to their common vector (*Anthophora urbana*). The relatively high level of NCP sustained throughout the season and marked decreases only at the very beginning and very end of the season of the Oceanside curve, differing radically from the others in these respects, suggests that in this site (where the ecology differs markedly from that of other localities) the vector or vectors are different species than those responsible in the other localities.

Conclusions

The differences in rates of NCP and in total seed production by male-sterile plants observed in different localities and, in certain instances, in harvests of successive years in the same locality, wholly exceed those anticipated from reports in the literature. It is possible that the great ecological differences of the various areas of tomato production in California plus the admitted intention to select localities of high and low insect activity are responsible for this deviation from previously published rates. It might also be possible that male-sterile plants are more sensitive to NCP because they fail to yield any functional pollen, and greater differences between localities might thereby be expected.

The variation in rates observed in different areas in this experiment greatly exceeds that found in various arrangements of fertile and male-sterile plants in a single locality (7) and indicates that selection of the proper locality is a more important factor for the production of hybrid seed by the natural cross method. It would seem logical, first to select the locality in which tomatoes are cross-pollinated at the highest rates and, at the same time, grow well, and secondly to experiment with various planting designs and other manipulations that might further increase the yields.

The ideal locality, providing the highest yields of hybrid seed by the NCP method, would be the one whose vectors maintain a high rate of NCP and whose growing conditions guarantee a reasonably high rate of flower production. The Capay region shows greater promise than any other locality tested in this experiment. Consistently higher rates of NCP and yields of hybrid seed were recorded, especially for plots close to the irrigation canal. A further search for localities of

high yields might be warranted, however, since summer conditions in Capay are not especially favorable for growth of tomatoes, as testified by the relatively low yields of fertile plants and low flower production of sterile plants. In spite of this drawback, male-sterile plants in the most favorable sites in Capay Valley could yield as many as 2,000,000 or about 10 pounds of hybrid seed per acre from NCP alone.

No attempt has yet been made to increase artificially the population density or rate of activity of the responsible insect vectors. The only recommendations in this respect to be gleaned from the present experience are negative; practices that discourage visits of the vectors should be limited to the greatest extent possible. Their solitary habits (excepting *Bombus sonorus*) seem to preclude any attempt to increase their number by artificial culture. In the light of present knowledge, therefore, it seems more fruitful to bring the plants to the insects than to bring the insects to the plants.

Summary

The rates of natural cross-pollination and the consequent yields of hybrid seed on male-sterile tomato plants were measured in small test plots in several localities in California during a three-year period. The results were obtained by observing directly the number of fruits and seeds and the proportion of flowers that set fruit on two male-sterile mutants of the San Marzano variety when interplanted with fertile plants of the same variety.

Yields of hybrid seeds on the male-sterile plants varied from 105 to 4,260 per plant, and, expressed as the percentage of the yield of fertile plants in the same plots, they varied from 1.9 to 47 per cent. In proportion of flowers that set fruit, the observed values fluctuated from 3.1 to 30.3 per cent; in terms of fertile-plant yield, from 5.9 to 65 per cent. The number of seeds per fruit varied less, the limits being 7.7 and 26.7.

Yearly yields of hybrid seed and rates of natural cross-pollination were found to be relatively very high in one locality (Capay) but were highly variable in others. Yields of 2,000 to 3,000 seeds per plant set by natural cross-pollination alone on male-sterile plants might be expected in the Capay region despite relatively unfavorable conditions for growth of tomatoes there.

Limited evidence suggests that yields of hybrid seed and rates of natural cross-pollination are not influenced markedly by the size of the planting, but they are apt to be higher in the vicinity of constant and exposed sources of water.

Comparisons reveal that plots differ greatly in the number of flowers per male-sterile plant and that the yield of hybrid seeds is considerably influenced thereby. It is suggested that rates of natural cross-pollination in the strict sense should not be based on total seed yields, but on the proportion of flowers that set fruit or the product of this measure and the mean number of seeds per fruit.

Seasonal variations in the rates of natural cross-pollination were ascertained partly by direct observations of the vectors themselves, but more extensively by examination of flower pedicels at the end of

the season. Although the curves of vector activity agree in a rise to a high maximum activity in midseason and decline to lower rates at either end of the season, many differences in other respects were observed, suggesting that different species of insects in different concentrations were responsible for pollen transfer in the various localities.

Except for a species of bumblebee observed at Riverside, various species of solitary bees are responsible for the pollination of tomatoes in localities where collections were made. The species *Anthophora urbana* Cressm. was collected most often and appears to be the most active vector of tomato pollen in California.

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An Investigation of the Yield Performance of Several Tomato Varieties[1]

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FOR many years Rutgers and John Baer have been the most popularly grown processing varieties in western New York. Growers, however, have become increasingly critical of these varieties after suffering substantial losses in tonnage due to the late maturity of Rutgers and the high incidence of blossom-end rot so often prevalent in John Baer. Because of the criticism of these varieties, tomato variety trials were conducted in Erie and Chautauqua Counties in 1947 and 48 to seek a more suitable variety for that area. Over this 2-year period, 25 hybrid and standard varieties were found to be no better suited than Rutgers and John Baer; however the varieties 46–31 and Improved Wasatch Beauty were found to give consistent, significantly greater yields than did these two varieties.

A study of blossom-end rot susceptibility of all varieties was made in 1948. Highly significant differences in susceptibility between varieties were obtained. The commercial varieties in these field experiments, therefore, showed not only differential yield response to the field conditions of western New York, but differences in blossom-end rot susceptibilty as well. This differential response of a group of varieties to a given set of conditions is usually obtained in most variety trials. The reason for these differences is commonly attributed to genetic variation between varieties. It seemed logical that some differences in expression of this genetic variation might become sufficiently manifest in the growth or physiological processes of the different varieties so that they could be measured.

Harvey (2) found that 23 varieties and species of tomato "showed consistent statistically significant differential growth on high and low levels of nitrogen, phosphorus and potassium solutions". He concluded that "the differential response to potassium levels (full and minus potassium) by tomato strains was inherited". Tiedjens and Schermerhorn (3) state that with tomato varieties "the highly vegetative types have a high metabolic rate, while the highly fruitful types have a relatively lower rate". In this statement the word "metabolism" was used synonymously with respiration.

Two greenhouse experiments, therefore, were designed to study the possible reasons for varietal differences in yield and blossom-end rot observed between varieties in the 1947 and 1948 field trials. The first greenhouse experiment was designed to study growth characteristics and physiological processes of several varieties in relation to their performances observed in the field experiments. A second experiment was conducted to investigate varietal efficiency in utilizing low amounts of

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nitrate, phosphate, and potassium. It seemed desirable to study as wide a range of varietal types as possible. Six varieties showing rather wide differences in habit of growth, blossom-end rot susceptibility, and yielding ability, therefore were chosen and are shown in Table I.

TABLE I—Vine Habit, Blossom-End Rot Susceptibility, and Yielding Ability of Six Tomato Varieties Grown in Experiments 1 and 2.

Variety	Habit of Growth	Yielding Ability	Blossom-End Rot Susceptibility
46-31	Indeterminate	High	Low
Gem	Determinate	Erratic	Low
John Baer	Indeterminate	Consistently low	Very high
Longred	Indeterminate	Erratic	Very high
Rutgers	Indeterminate	Consistently low due to late maturity	Low
Improved Wasatch Beauty	Determinate	Consistently high	Very low

Studies of the dry weight of roots and tops, root/top ratios, water and nutrient absorption, respiration, and photosynthesis seemed the most practical method of approach to this problem. These studies were made in the greenhouse and laboratories of the United States Plant, Soil and Nutrition Laboratory, Ithaca, New York. Only those studies concerning the dry weight of roots, tops, water and nutrient absorption, and respiration will be reported in this paper.

Experiment 1

Seeds of the six varieties were sown on December 7, 1948, in flats of quartz sand, and were watered with distilled water. At the age of 3 weeks, when all seedlings had developed two true leaves, they were pricked off and the roots carefully rinsed in distilled water. Twenty-four uniform seedlings were selected from each variety. Three seedlings of each variety were transferred to aerated, 9-liter battery jars containing Hoagland's Solution 2. Six jars representing the six varieties were randomized to give one replicate. Eight replicates of six varieties each were arranged in a randomized block design.

All jars were equally spaced near the center of a 65 to 75 degrees F greenhouse. The initial pH of all cultures was 5.5. Solutions were changed with sufficient frequency to maintain good growth throughout the period of the experiment.

Four harvests of the tops and roots of two replicates each were made. The first harvest was made 9 weeks after the seedlings were placed on the nutrient solution, the second after 12 weeks, the third after 14 weeks, and the last harvest after 15 weeks. Just prior to the first harvest an electric switch which controlled the air compressor was accidently turned off. All aeration, therefore, was stopped for approximately 24 hours before the error was discovered. This caused moderate wilting of all plants from which they did not recover for nearly 48 hours. Some sloughing off of roots was subsequently noted when the first harvest was made. Each harvest was made immediately following a water and nutrient-absorption study. Methods used in that study will be described later.

At each harvest, plants were removed from the culture jars, the roots excised from the tops and the water removed by blotting. Fresh weights of roots and tops were determined separately. They were then dried at 70 degrees C in a forced draft oven to constant weight and dry weights to the nearest tenth gram were recorded. Mean dry weights of roots and tops of the six varieties for four harvest dates are summarized in Table II.

TABLE II—MEAN DRY WEIGHTS OF ROOTS AND TOPS OF SIX TOMATO VARIETIES GROWN IN EXPERIMENT 1

Harvest Date	Weight (Grams)	Variety					
		46-31	Gem	John Baer	Longred	Rutgers	Improved Wasatch Beauty
Mar 9	Roots	3.55	2.90	3.60	3.20	2.70	4.65
	Tops	23.25	18.50	23.75	20.75	16.25	25.50
Mar 27	Roots	8.15	3.30	6.90	4.35	9.00	10.55
	Tops	57.00	22.50	46.75	30.00	57.50	59.50
Apr 6	Roots	7.70	5.40	5.90	7.35	7.05	7.10
	Tops	60.00	42.50	49.00	52.50	85.50	46.00
Apr 14	Roots	12.10	9.70	9.70	5.65	6.10	8.20
	Tops	85.00	64.00	64.00	38.50	62.50	49.00

No significant differences were found in dry weight of tops between varieties. A comparison of mean dry weight of tops between indeterminate and determinate varieties failed to reveal any significant differences between the means. It is not surprising that no significant differences in dry weight of tops were found between varieties in solution culture, since no great differences in the vine habit of the tomato becomes manifest under field conditions until well after plants are 4 months old. All varieties in this experiment represented standard types; the greatest difference in the vine growth being between the determinate and indeterminate habit of growth. Evidence from these studies suggests that there was no relationship between dry weight of tops of varieties grown in solution culture and yield of fruit in the field.

The analysis of variance of the dry weights of roots showed no significant differences between varieties. A "t" test comparison of the mean dry weight of roots between determinate and indeterminate varieties also showed no differences.

Since Improved Wasatch Beauty and 46–31 were found in field experiments to give high yields, a comparison was made of their mean dry weight of roots with the mean dry weights of roots of the four low and erratic yielding varieties and are given in Table III.

The high yielding varieties had a highly significantly greater dry weight of roots than did the other varieties.

Assuming equal rates of absorption of nutrients and water per unit of root weight, the greater the weight of roots the greater the amount of nutrients absorbed. Since the higher yielding varieties had greater dry weight of roots, the higher yield of these varieties may be related

TABLE III—MEAN DRY WEIGHT OF ROOTS OF TWO HIGH YIELDING VARIETIES COMPARED TO FOUR LOW AND ERRATIC YIELDING VARIETIES

Yield Classification	Mean Weight (Grams)
Two high yielding varieties	7.75
Four other low and erratic yielding varieties	5.80
Calculated "t" for high versus four other varieties	2 89
Required "t" for high versus four other varieties (0 01)	2.80

to potentially greater water and nutrient absorption capacity, especially under adverse conditions.

As was previously mentioned, water and nutrient absorption studies were made just prior to each harvest. Two replicates were transferred from the greenhouse solution cultures to dilute, uniformly aerated Hoagland's Solution 2 cultures in a room controlled to give uniform light and temperature.

Roots of all plants were rinsed twice in distilled water as they were transferred from the greenhouse to the constant environment room. They were then placed in calibrated, 9-liter culture jars containing a .1 normal concentration of Hoagland's Solution 2 and arranged in random order. All cultures were continuously aerated by sintered glass aerators calibrated by a "c" clamp flowrator to deliver 220 to 260 cc air per minute. Air temperature of the room was thermostatically controlled at 21± 1 degree C. Continuous illumination of approximately 800 foot candles was provided by a bank of fluorescent lights composed of an equal number of white and daylight tubes in alternating order.

Duration of the absorption determinations was arbitrarily controlled by the time that was required for at least one variety to exhaust approximately three-fourths of the nutrients from the solution in which it was growing. Extent of exhaustion was determined by resistance measurements made with a cathode ray tube, RC1 conductivity bridge at 21 degrees C.

Solution levels were brought to the calibrated marks with distilled water and aeration was allowed to proceed for 1 hour just prior to making each resistance reading to give uniform mixing of the added water. Initial resistance measurements were made immediately after the plants were placed in the solutions. Results from an aerated check solution showed that no error in resistance readings was introduced by carbon dioxide present in the air stream. All volumes of distilled water added to the cultures of the different varieties were recorded.

The amount of water absorbed by the different varieties was calculated on the basis of milliliters per gram fresh weight of top. A study of these data revealed that the six varieties gave almost identical readings on this basis. There was no significant difference between a minimum absorption of 2.1 milliliters per gram fresh weight of tops for Rutgers and a maximum of 2.5 milliliters for 46–31. Transpiration apparently controlled the amounts of water absorbed, since the plants were grown on a nutrient solution and their roots were never subjected to any stress from a deficiency of water. The quantity of water absorbed by the different varieties in culture solution, therefore, does not

appear to bear any relation to their yields or susceptibility to blossom-end rot found in the field.

The duration of the absorption determinations varied from 174 hours for the first harvest to 48 hours for the last two harvests. A part of the variation probably was due to age of the plants, but it is believed that the extreme length of time required for absorption in the first harvest was due to root injury caused by the accidental stoppage of aeration as mentioned previously.

Initial resistance readings of all cultures varied only slightly from 460 ohms; therefore, a statistical analysis of the resistance readings of all culture solutions at the end of the nturient absorption determinations seemed justified. Final resistance readings for all cultures are presented in Table IV.

TABLE IV—FINAL RESISTANCE READINGS IN OHMS FOR ALL CULTURE SOLUTIONS IN WHICH SIX TOMATO VARIETIES WERE GROWN

Variety	Replication							
	1	2	3	4	5	6	7	8
46 31	730	1,500	1,500	5 750	2,110	620*	11,700	4,480
Gem	800	1,000	625	1,075	570	1,955	2,510	3,900
John Baer	790	1,575	2 950	2 600	2,075	2,080	2,550	900
Longred	965	1,250	720	2,400	2,030	2,450	6,050	525
Rutgers	805	590	1,575	2,900	2,110	1,985	1,585	590
Improved Wasatch Beauty	815	3,900	3,900	2,600	2,030	1,950	1,315	5,650

*Aerator clogged for 24 hours.

Logarithmic transformations of all resistance values were made and statistically analyzed. When the mean log values of the solutions in which the two high-yielding varieties were grown were compared by the "t" test with that of the solutions in which the other varieties were grown, it was found that the former had a higher resistance, that is, they had absorbed more nutrients than the erratic and lower-yielding varieties. The high-yielding varieties also had the greatest dry weight of roots. This higher uptake of nutrients, therefore, was probably due to the larger root systems rather than greater absorbing capacity per unit of weight of the roots. From these results, it would appear that the varieties giving high yields in the field experiments also produced heavier roots and absorbed more nutrients when grown in culture solution than did those varieties which yielded low or erratically in the field experiments.

To ascertain any possible differences in rates of respiration between varieties, a method of simultaneously measuring respiration of several replicates of the six varieties was required. Bonner and Wildman (1) reported that highly reproducible rates of gas exchange were obtained from spinach leaf fragments in a phosphate buffer measured in the Warburg respirometer. The authors of this paper, however, obtained only very erratic measurements of oxygen uptake from 20, ¼-inch leaf discs by using this method. When discs were placed on moistened filter paper in the bottom of the Warburg flasks without a buffer, however, uniform readings of oxygen uptake were obtained between replicates of the same leaf.

With the model of the Warburg apparatus available for this work, respiration of two full replicates of the six varieties could be determined simultaneously. Measurements were made by the oxygen absorption method for measuring respiration described by Umbreit, Burris, and Stauffer (4) except that the method was modified by eliminating the buffer and substituting moistened filter paper. All measurements were made at 25 degrees C in a darkened room. Two-tenths milliliter of 20 per cent potassium hydroxide was used in the center well of each flask to absorb the carbon dioxide. After measurements of oxygen uptake were made of the disc samples, they were dried to constant weight and their dry weights recorded. Calculations of oxygen uptake were made to convert the values to microliters (µl) uptake of oxygen per milligram dry weight of the leaf discs. These data were then statistically analyzed and the results given in Table V.

TABLE V—Oxygen Consumption of Leaf Discs of Six Tomato Varieties (Microliter Oxygen Absorbed per Milligram Dry Weight per Hour)

Variety	Replications				Mean	
	1	2	3	4		
46 31	2.26	1.62	2.31	2.21	2.10	Mean for high-yielding varieties: 2.02
Gem	3.02	2.25	2 22	2.92	2 60	
John Baer	2.48	2 37	2 24	2.22	2 33	
Longred	2 14	1 90	1 75	2.71	2 12	
Rutgers	2.39	2 09	1.87	2 17	2.13	Mean for other four: 2 30
Improved Wasatch Beauty	2 12	1.64	1 64	2.07	1.94	

Least Difference (0.05)	0 37
Calculated "t" for high yielding varieties versus others	2.63
Required "t" for high yielding varieties versus others (0.05)	2 14
(0.01)	2.97

The data in Table V show that there were no significant differences in rates of respiration between John Baer and Gem; however, 46–31, Longred, Rutgers, and Improved Wasatch Beauty had a significantly lower rate of respiration than did Gem. By means of a "t" test the mean rate of respiration of the high-yielding varieties was compared with the mean rate of respiration of the other varieties. This comparison showed that the high-yielding varieties had a significantly lower rate of respiration than did the other varieties.

Experiment 2

In this experiment the six tomato varieties were grown on restricted nutrient solutions to study any possible differences in their efficiency of utilization of low amounts of nitrate, phosphate, and potassium. Seeds of the six varieties were sown in flats of quartz sand on February 10, 1949, and were watered with distilled water. At the age of 5 weeks seedlings were transferred to aerated 500 ml brown-bottle culture jars. Four nutrient treatments were used; full Hoagland's solution 2, full except .1 nitrate, full except .1 phosphate, full except .1 potassium.

Varieties and treatments were completely randomized in four replications. There were no significant differences between varieties in root

and top growth produced on the full, low nitrate, and low phosphorus treatments. The mean dry weights of roots and tops produced by the six varieties on low potassium are shown in Table VI.

TABLE VI—MEAN DRY WEIGHT OF ROOTS AND TOPS OF SIX TOMATO VARIETIES GROWN ON THE LOW POTASSIUM TREATMENT

Variety	Weight (Grams)		
	Roots	Tops	
46-31	0.40	1.20	Mean for other five varieties
Gem	0.39	1.52	
John Baer	0.65	1.82	
Longred	0.45	1.45	Roots 0.42
Rutgers	0.38	1.06	Tops 1.32
Improved Wasatch Beauty	0.49	1.36	
Mean	0.46	1.40	

Calculated "t" for John Baer versus five other varieties—roots	2.54
—tops	2.30
Required "t" for John Baer versus five other varieties roots and tops (0.05)	2.01
(0.01)	2.68

By means of a "t" test, a comparison was made of the mean dry weights of roots and tops produced by John Baer on the low potassium treatments with the mean dry weights of roots and tops produced by the other five varieties. John Baer was found to have produced a significantly heavier root growth and top growth than did the other varieties. This would indicate that John Baer was more efficient in its utilization of low amounts of potassium than were the other varieties. The more efficient utilization of low potassium exhibited by John Baer may be due to some factor in the genetic constitution of that variety.

Summary

Results of the two experiments reported may be summarized as follows:

No relationship was found between the dry weight of tops of the six varieties grown in culture solution and their yield performance in the field. Varieties producing high yields in the field experiments, however, produced a highly significantly greater dry weight of roots and absorbed significantly more nutrients when grown in culture solution than did those varieties which yielded low or erratically. The greater absorption of nutrients by the high-yielding varieties was probably due to their larger root systems.

The varieties which produced high yields in the field were found to have a significantly lower rate of leaf respiration than did those varieties which produced low or erratic yields. These results are in agreement with the work of Tiedjens and Schermerhorn (3).

The variety John Baer produced a significantly heavier dry weight of tops and roots on the low potassium treatments than did the other five varieties with which it was compared. This more efficient utilization of potassium by John Baer may be due to some factor in its genetic constitution. A differential varietal response to low potassium was noted by Harvey (2) and he concluded that it was inherited.

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The Importance of Time of Application of "Hormone" Sprays to Improve Greenhouse Tomato Yields[1]

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IN THE USE OF synthetic growth-regulating substances ("hormones") to improve set and size of greenhouse tomatoes considerable emphasis has been placed on proper concentrations, but the timing of the application has been stressed little. Usually spraying is begun when the first flowers open, but in fruit setting studies with hormones at the Missouri Agricultural Experiment Station (2,3) it has been observed that best results are obtained if sprays are delayed until three or more flowers of the cluster are open. Also general observations have indicated that in the case of whole plant spraying the upper portion of the plant containing unopened flower clusters should not be sprayed. Roberts and Struckmeyer (4) have shown that both the percentage set of fruit as well as size of individual fruits depends upon the time of application of the fruit-setting chemicals.

The present studies were conducted to collect further data on the effects of growth-regulating substances on flower bud development and to determine the stage of flower development which will give maximum fruit set and size with hormone application.

MATERIALS AND METHODS

Plants, var. Master Marglobe, used in these experiments were grown in a medium of two-fifths clay loam, two-fifths mold, and one-fifth river sand in concrete benches in a greenhouse. They were spaced 2 by 2 feet, staked, and trained to a single stem. All growth-regulating substances were applied as aqueous sprays with a small hand atomizer.

Except where noted each bud or flower was sprayed individually and only once. For "bud stage" treatments the spray was applied approximately 8 days prior to anthesis, for "anthesis stage" treatments the flower was sprayed when fully open, and with "post-anthesis stage" treatments flowers were sprayed 4 days after fully open.

Pollination was facilitated by tapping the clusters twice weekly while in bloom.

Yield records are based on fruit of a marketable size (3 ounces and over).

EXPERIMENT I — WINTER 1946–1947

The growth-regulating substance, p–chlorophenoxyacetic acid (ClPA), was selected for this experiment, because it has been shown to be one of the most effective of the hormones for fruit-setting (2,3). The plants were divided into four groups, of fourteen each, and were treated as follows:

1. ClPA—10 ppm (bud stage)
2. ClPA—10 ppm (anthesis stage)
3. ClPA—10 ppm (whole cluster treatment). Spray applied once to whole cluster when the first three flowers were open.
4. Control—no treatment.

[1]Contribution from the Department of Horticulture, Missouri Agricultural Experiment Station, Journal Series No. 1154.

Results from this experiment are presented in Table I. ClPA, 10 ppm, applied to the flower at anthesis gave an increase in yield of fruit (42.64 per cent) resulting from an increased number and a larger average size of fruit. When this chemical was applied to the bud, approximately 8 days before anthesis a marked reduction in yield (28.41 per cent) resulted, due both to decrease in number of fruit set and a smaller average size of fruit.

TABLE I—EFFECTS OF P-CHLOROPHENOXYACETIC ACID ON YIELD OF TOMATOES WHEN APPLIED AT DIFFERENT STAGES OF DEVELOPMENT (CONCENTRATION 10 PPM, AVERAGE FOR 10 PLANTS—WINTER 1946–47)

Stage of Flower Development When Treated	Number of Marketable Fruit Harvested	Increase or Decrease Due to Treatment (Per Cent)	Average Weight per Fruit (Pounds)	Increase or Decrease Due to Treatment (Per Cent)	Total Weight of Fruit Harvested (Pounds)	Increase or Decrease Due to Treatment (Per Cent)
Bud stage	92	-23.33	0.241	-6.58	22.18	-28.41
Anthesis stage	158	+31.66	0.277	+7.36	43.77	+42.64
Whole cluster flowers and buds present	144	+20.00	0.263	+1.93	37.86	+22.20
Control, no treatment	120	———	0.258	- -	30.98	———

A number of the buds treated before anthesis did not exhibit normal development. Opening was delayed, and some failed to open even though they persisted on the cluster.

Evidently treatment affected the developing pollen grains or ovules or both for most of the fruit were seedless. These seedless fruits were abnormally flattened, ridged, and had very large stem scars. Only a small percentage would have been marketable because of the undesirable shape and general appearance, even though they were of a marketable size.

Spraying the whole cluster after three flowers had opened resulted in greater yield than that of the controls, but the increase was less than that of plants with individual flowers treated at the anthesis stage.

EXPERIMENT II — SPRING AND SUMMER 1947

It was thought desirable to determine the influence upon yield of certain other hormones, in addition to p-chlorophenoxyacetic acid (ClPA) when applied at different stages of development. The chemicals chosen were α-naphthaleneacetic acid (NA) and β-naphthoxyacetic acid (NOA).

A group of plants was divided into seven lots of 12 plants each. The growth-regulating substances were applied at two different stages of development, as shown in Table II.

This experiment was conducted during the period April to July when hormone treatment would be least effective in augmenting yield of greenhouse tomatoes because light intensity and duration are sufficient to permit the plant to develop normal floral parts.

Data presented in Table II show that an appreciable decrease in yield resulted from "bud stage" sprays with all three "hormones". With treatment at anthesis ClPA and NOA increased yields while NA showed no beneficial or detrimental influence.

TABLE II—EFFECTS OF p-CHLOROPHENOXYACETIC, α-NAPHTHALENEACETIC, AND β-NAPHTHOXYACETIC ACIDS ON YIELD OF TOMATOES WHEN APPLIED AT TWO STAGES OF DEVELOPMENT (AVERAGE FOR 10 PLANTS— SPRING 1947)

Treatment	Number of Marketable Fruit Harvested	Increase or Decrease Due to Treatment (Per Cent)	Average Weight per Fruit (Pounds)	Increase or Decrease Due to Treatment (Per Cent)	Total Weight of Fruit Harvested (Pounds)	Increase or Decrease Due to Treatment (Per Cent)
ClPA—10 ppm Bud stage	166	-8.79	0.346	-2.81	57.48	-11.24
ClPA—10 ppm Anthesis stage	206	+13 19	0.363	+1.97	74.45	+15.42
NA—20 ppm Bud stage	172	-5 49	0 327	-8 15	56.27	-13.11
NA—20 ppm Anthesis stage	191	+4 95	0.337	-5.34	64.35	-0.63
NOA—50 ppm Bud stage	174	-4 39	0 340	-4 49	59.20	8.59
NOA—50 ppm Anthesis stage	195	+7.14	0 368	+3 37	71 73	+10 76
Control no treatment	182	—	0.356	—	64 76	—

EXPERIMENT III — WINTER 1947–1948

The presence of seeds in a fruit usually favors its maximum development. Hormones applied during pollination decrease seed formation, hence, a post-fertilization application might be more beneficial than at earlier stages. It is known that the ovaries of tomato flowers are subject to stimulation even after the petals have begun to wither (4) therefore it was thought desirable to compare the effect of hormone sprays applied after fertilization has occurred with those applied at earlier stages.

For this experiment flowers 4 days after they had opened were selected as being in post-fertilization stage. According to Judkins (1), fertilization in the tomato usually will have occurred in 4 days or less after pollination.

A lot of plants was divided into nine groups of 10 each. ρ–Chlorophenoxyacetic and α–naphthaleneacetic acids were applied at three stages of development: "bud-stage" (approximately 8 days before anthesis), "anthesis stage" (when flowers were fully open), and "post-fertilization stage" (4 days after fully open).

In Table III, it will be noted that "bud stage" sprays again reduced

TABLE III—EFFECTS OF p-CHLOROPHENOXYACETIC AND α-NAPHTHALENE-ACETIC ACIDS UPON YIELD OF MARKETABLE GREENHOUSE TOMATOES WHEN APPLIED AT DIFFERENT CONCENTRATIONS AND STAGES OF DEVELOPMENT (AVERAGE FOR 10 PLANTS—WINTER—1947–48)

Treatment	Number of Fruit of Marketable Size	Increase or Decrease Due to Treatment (Per Cent)	Total Weight of Fruit (Pounds)	Increase or Decrease Due to Treatment (Per Cent)
ClPA-10 ppm bud stage	117	-23.03	36.31	-21.91
ClPA-10 ppm anthesis stage	181	+19.08	52.38	+12.65
ClPA-10 ppm post-anthesis stage	196	+28.95	54.63	+17.48
ClPA-20 ppm post-anthesis stage	190	+25.00	59 48	+27.91
NA-20 ppm bud stage	103	-32.24	32.63	-29.83
NA-20 ppm anthesis stage	151	-0.66	40.86	-12.13
NA-20 ppm post-anthesis stage	158	+3.95	44.12	-5.12
NA-40 ppm post-anthesis stage	149	-1.97	40.25	-13.51
Controls	152	—	46.50	—

yields. Flower development, as indicated by date of opening, was retarded. Histological examination of buds 4 days after treatment showed that 25 to 100 per cent of the pollen grains had collapsed and ovule development, in most cases, had been retarded or completely inhibited.

ClPA applied at anthesis improved set of fruit, but the greatest increase in yield resulted from post-anthesis sprays with the higher concentration giving the largest yield. Fruits from flowers treated at the "post-anthesis stage" contained more seeds than fruits from flowers sprayed at the "anthesis stage". NA, 20 ppm, caused a smaller reduction in yield when applied 4 days after anthesis than when applied at anthesis or 8 days before anthesis, however, higher concentrations of NA caused considerable reduction in yield even at the post-anthesis stage.

Discussion and Summary

To secure maximum benefit from "plant hormones" not only must the proper concentration be used but the chemical must be applied at the proper stage of development. Results of experiments reported herein indicate that hormone sprays at concentrations most effective for fruit-setting are detrimental when applied approximately 8 days before anthesis. Normal flower development was inhibited, and both fruit set and size were reduced. The majority of the fruit which did develop were seedless or only partially seeded due to injury to the pollen grains and ovules.

Spraying flowers when fully open increased set and size of fruit over controls, but hormones applied 4 days after anthesis gave the greatest increase in yield.

Fruits from flowers treated 4 days after anthesis contained more seeds than those from flowers sprays at anthesis. Seeds are usually beneficial to maximum fruit size, and, perhaps, the greatest yield is due to the presence of more seeds per fruit.

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Tomato Lines of Lycopersicon Esculentum Type Resistant to Tobacco Mosaic Virus[1]

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In a preliminary report from the Hawaii Agricultural Experiment Station, Kikuta and Frazier (8) presented data on tobacco mosaic[2] virus resistance in progeny of certain complex tomato species hybrids. At the time of that report the material was extremely heterozygous, and it was recognized that several additional generations would be required before an idea could be obtained as to whether the resistance could be successfully transferred to *Lycopersicon esculentum* type lines. It is the purpose of the present paper to show the degree of apparent resistance that has been maintained after further hybridization and selection for improved horticultural characters.

Parentage of Resistant Lines

While large numbers of selections, with varied parentage, have been carried in these tests, the lines have been narrowed down to the relatively few of greatest promise. Data on selections within these most promising lines will be presented here. These lines, with their parentage, follow:

A. HES[3] 3390, 3391, 3392 lines, derived from the cross: 2524 *(L. esc.*[4]*)* × { 2269 *(L. esc.)* × [*(L. peruv.* — MSF × *L. pimp.)* × *L. hirs.*] }

The 2524 and 2269 *Lycopersicon esculentum* lines were developed in Hawaii in other phases of tomato improvement (3) and carried resistance to fusarium wilt *(Fusarium oxysporum, F. lycopersici)*, spotted wilt, and gray leaf spot *(Stemphylium solani)*. The cross listed here is merely a backcross of the T–3400 reported earlier (8) to 2524.

B. 3299 lines: Same as A, except delete 2524; thus, 3299 is a straight selection from T–3400.

[1]Published by permission of the Director of the Hawaii Agricultural Experiment Station as Technical Paper No. 186.

[2]The abbreviation TM will hereafter be used in this article to refer to tobacco mosaic (tomato mosaic) *(Marmor tabaci* H.)

The *Lycopersicon peruvianum* × Michigan State Forcing cross shown in the parentage of the lines discussed in this paper was made by Dr. A. F. Yeager, who supplied F_3 seed to us; *L. hirsutum* was supplied by Dr. S. P. Doolittle; *L. pimpinellifolium* came from the Division of Plant Exploration and Introduction of the Bureau of Plant Industry, Soils and Agricultural Engineering, U. S. Department of Agriculture. Original isolation of the TM virus strain used in these tests was done by Dr. F. O. Holmes while on a visit to Hawaii. The senior author wishes especially to express his appreciation for the assistance given by K. Kikuta in the early phases of this work.

[3]HES refers to Hawaii Agricultural Experiment Station selection numbers. Hereafter, the HES will be deleted from Hawaii selection numbers for brevity.

[4]Abbreviations: *L. esc., Lycopersicon esculentum; L. peruv., L. peruvianum;* MSF, Michigan State Forcing; *L. pimp., L. pimpinellifolium; L. hirs., L. hirsutum.*

C. 3399 lines: 3095 × { 2524 × [2269 × (*L. peruv.* — MSF — *L. pimp.* × *L. hirs.*) × (*L. peruv.* — MSF — *L. pimp.* × *L. hirs.*)] }

The 3095 was an *Lycopersicon esculentum* type developed for resistance to fusarium wilt, spotted wilt, and gray leaf spot (3).

Testing Methods

Source of TM inoculum has been dried leaves of tomatoes which were infected with the yellow, distorting strain of TM virus previously used (8). Leaves have been air dried and kept in a desiccator over calicum chloride until ready for use. Five grams of dry leaf tissue have been ground in a mortar, with approximately ¼ teaspoonful of 400-mesh carborundum. One hundred cubic centimeter of water has then been added, and inoculation performed as suggested by Holmes (4). Leaves of each young seedling are gently rubbed with a cotton swab which has been dipped into the inoculum. Seedlings have been inoculated 2 to 4 weeks following sowing of seed. In the moderately cool weather of winter, seedlings grow more slowly than in summer, thus necessitating delay in testing. In some cases, a second inoculation has followed within 1 or 2 weeks. After susceptible plants have been eliminated in the seedling stage, the remaining, apparently resistant, ones have been transplanted to field plots. The field plots have been used repeatedly for growing tomatoes for TM tests — one planting closely following the other — thus adding to the severity of the over-all TM tests to which plants are subjected through possible inoculation from soil, as indicated by Johnson (7).

FIG. 1. Tomato seedlings 13 days after inoculation with a severe yellows strain of tobacco mosaic virus. Left, a plant of 3391 (3870), free of symptoms. Right, a plant of Pearl Harbor, showing severe chlorosis and considerable distortion of young leaflets.

Check (susceptible, inoculated) plants have been transplanted to the field plots for comparison with resistant lines in late stages of growth. Plants have been selected or eliminated on the following basis:

a. Earliness of appearance of symptoms; even though symptoms were mild, plants have been discarded if mottling, or distortion of leaves were present in young seedlings.

b. Relative symptom expression of mature plants; only plants which have shown mild or medium mottling when fruits mature have been selected. Mature plants with severe symptoms of mottling or leaf distortion have been eliminated regardless of rather good yields in some cases.
c. Vigor of plants at maturity; the most vigorous types have been retained, although 3390 and 3391 have never been distinctly vigorous.
d. Yield of plants; in general selections have been based on ability of mature plants to produce good yields in spite of mild to medium TM symptoms. A few lines such as 3299, however, have been retained primarily for their resistance.

Records of appearance of symptoms have, for purposes of simplification, been modified from time to time. In most instances, plants have been placed in two categories: (a) completely free of symptoms; or (b) showing mild, medium, or severe symptoms. In other tests, to secure occasional readings on apparent gradations in mottling, plants have been classed as 0, free of symptoms; 1, mild mottling; 2, medium mottling; and 3, severe, yellow, mottling and/or leaf distortion. Thus, one class has been eliminated from the 0, 1, 2, 3, 4 system previously used by Kikuta and Frazier (8).

Results

Test TM–4:—The F_1 hybrid, from which 3390, 3391 and 3392 lines were later derived, was planted in this test. Seeds were planted January 28, 1947; seedlings were transplanted to flats February 8, and inoculated with TM virus February 18. On February 27 data were secured on TM symptoms. Resistant plants were transplanted to the field March 7. Of 55 Pearl Harbor plants, used as checks, all showed severe TM symptoms on February 27; of 75 plants of the F_1 hybrid, 45 were susceptible, with varying degrees of mottling; of the remaining 25, 13 were eliminated in the field on March 20 after showing medium to severe mottling, leaving 12 from which to make selections. One selection, given a selection number 3118, was especially promising.

Test TM–5:—In this test progeny of 3118 (F_1 plant selected from above cross tested in TM–4) were compared to Pearl Harbor. Seeds were planted June 1, 1947; seedlings were transplanted to flats June 10, and inoculated with TM virus June 17. On July 2, data were secured on TM symptoms, and plants transplanted to the field. At this date the 95 Pearl Harbor plants used as checks showed TM symptoms; of 80 plants of 3118, 16 were eliminated. In the field, 41 additional 3118 plants were eliminated for TM symptoms. The 23 remaining plants showed very mild mottling, but 20 were rather unproductive, leaving 3 for selection. Seeds of the three most promising (3281, 3282 and 3283), along with several other lines, were planted for the next test, TM–6.

Test TM–6:—Data for this test, including planting and inoculation dates, are shown in Table I. Line 3285, with sources of resistance to

TM virus similar to the other lines, was included to compare with the F_1 hybrid (3285 × susceptible) ; an F_1 of 3281 × susceptible was also included.

TABLE I—TEST TM6: RESISTANCE OF TOMATO LINES AND F_1 HYBRIDS TO TOBACCO MOSAIC VIRUS*

Line	Total No. Plants Tested	Number of Plants Eliminated Because of TM Mottling on Indicated Dates†					Number Without Symptoms	Number Without Symptoms
		Dec 11	Dec 21	Jan 2	Jan 16	Feb 5	Feb 5	Apr 27 (Field)
Pearl Harbor	108	108**	—	—	—	—		
3281 F_3	42	13	2	11	3	7	6	0
3281 ×susceptible F_1	52	27	2	16	5	2	0	0
3391 (3282) F_3	31	7	3	6	0	4	11	0
3390 (3283) F_3	22	0	0	1	0	13	8	0
3285 F_3	61	24	9	14	8	6	8	0
3285 ×susceptible F_1	72	19	18	16	3	2	14	0
3299 F_4	48	3	4	2	2	10	27	0
T-3765‡ F_1	49	14	7	14	5	3	6	0

*Seeds planted November 20, 1947; first TM inoculation December 3; second TM inoculation December 12.

**All plants thereafter, when planted to field, retained medium to severe mottling symptoms.

†Pearl Harbor plants retained for planting to field, all susceptibles appearing in segregating lines were discarded.

‡For parentage of T-3765 see discussion of parentage of resistant lines under "C" in text.

Ability of many plants to grow for prolonged periods without development of TM symptoms following heavy inoculation is clearly shown in the table. All plants of Pearl Harbor and other commercial types of tomatoes used as checks have shown 100 per cent infection at an early date in these tests. The data are rather typical of the behavior of resistant lines in that development of symptoms within given time periods is shown to vary widely for individual plants, until finally, after plants have been in the field for several weeks, all plants are classified as susceptible. Many, however, show no more than mild symptoms. This behavior persisted in tests TM–7 and TM–8, and also, as will be noted, in a recent test TM–9 (Table II).

An interesting feature of Table I is the apparent high degree of dominance of resistance exhibited by the two F_1 hybrids, which rather closely parallel the behavior of the resistant parent. While in some instances F_1 hybrids appear to show even a greater lag in symptom development than resistant parents, it has been more common to find slightly less resistance in the F_1. Since the material under study has presumably been heterozygous for resistance, it is sufficient simply to note that there is a rather high dominance of resistance.

Test TM–9:—Data for this test are presented in Table II. In addition to readings made January 31 for susceptibility in seedling stages, plants were classified in the field at 6½ and 10 weeks following initial inoculation; at 10 weeks (March 14) the variations in symptom expression were also noted.

Four weeks following inoculation (January 3 to January 31), all plants of Pearl Harbor showed mottling, while most plants of selections from lines 3299, 3390, 3391 and 3392 were free of symptoms. The 3399 line was represented by several individual plant selections, all of which showed resistance intermediate between that of Pearl

TABLE II—TEST TM9: RESISTANCE OF TOMATO LINES AND F_1 HYBRIDS TO TOBACCO MOSAIC VIRUS*

Line		Seedling Susceptibility				Field Susceptibility				
						Susceptible Rating Mar 14				No. Entirely Free of Symptoms Mar 26
		No. Tested	No. Susceptible Jan 31	No. Transplanted†	No. Susceptible Feb 18	0 None	1 Slight	2 Medium	3 Severe	
Pearl Harbor		20	20	15	15	—	—	6	9	0
3299 (3693)	F_5	40	0	14	2	—	11	3	—	0
3299 (3689)	F_5	37	0	18	8	1	15	2	—	0
3390 (3839)	F_6	29	4	20	8	—	15	5	—	0
3390 (3842)	F_6	16	0	14	4	—	8	6	—	0
3391 (3836)	F_6	34	0	33	15	—	24	8	1	0
3391 (3870)	F_6	27	0	25	2	1	23	1	—	0
3391 (3872)	F_6	18	2	11	2	—	5	6	—	0
3391 (3869)	F_6	20	0	19	12	—	15	4	—	0
3391 (3869) ×susceptible	F_1	25	0	24	11	—	6	17	1	0
3392 (3687)	F_6	20	0	9	4	—	6	3	—	0
3392 (3687) ×susceptible	F_1	9	0	8	5	—	1	7	—	0
3399 (3858)	F_4	40	33	4	4	—	—	3	1	0
3399 (3865)	F_4	39	13	17	11	—	—	15	2	0
3399 (3946)	F_4	40	21	9	?	—	—	6	3	0
3399 (4017)	F_4	40	15	14	8	—	1	11	2	0
3399 (4018)	F_4	40	18	18	18	—	—	13	5	0
3399 (4019)	F_4	40	19	13	13	—	.	9	4	0
3399 (4023)	F_4	40	4	25	14	—	3	21	1	0

*Seeds planted December 2, 1948, first TM inoculation January 3, second TM inoculation January 11

†For resistant lines, only plants free of symptoms on January 31 were transplanted to field; others were discarded. Pearl Harbor susceptibles were, however, transplanted to the field.

Harbor and lines of the 3391 type. There were indications of gradations of resistance between 3399 selections also — 4023, for example, tending to show symptoms at later dates than others.

At 10 weeks (March 14) following inoculation, classification on basis of degree of mottling revealed that lines relatively free of symptoms January 31 and February 18 were in general the least severely mottled on March 14. Two plants free of symptoms March 14 had become mottled by March 26, thus corroborating earlier evidence that within this material the ultimate development of at least mild symptoms can be expected. Yet the decided delay in development of symptoms and mild eventual symptoms displayed by a line such as 3391 (3870) has offered encouragement to proceed toward the goal of developing commercially acceptable tomatoes with this type of resistance.

The 3390 and 3391 lines are determinate plum or cherry tomatoes, 1 to 1½ inches in diameter, fruitful, rather early, deep red in color when mature and highly compatible with commercial tomatoes. One characteristic has persisted — a tendency toward low germination of seed, the reason for which is not now known. The number of seeds per fruit has been low.

The 3399 line has been carried for superior horticultural characters, with fruits 2 to 4 inches in diameter, with excellent vigor and good yields. It may be necessary to cross to 3390 or 3391 types to regain a higher level of resistance, however. In spite of the fact that many selections from 3399 have been made for red fruit color, all have segregated

thus far for yellow skin and light flesh colors. It remains to be seen whether there is a possible close association between this color factor and resistance to TM virus. No such difficulty was experienced with 3390 or 3391 types.

Discussion

Of what value is the type of resistance exhibited by these tomatoes? We do not know the answer to this vitally important practical question. While it may be possible now to secure a partial answer by carefully controlled tests of infected versus virus-free resistant plants compared to infected versus virus-free susceptible ones, the fact remains that the most satisfactory answer must await development of desirable, heavy yielding commercial types carrying genes for resistance. We say genes, for it appears that there must be more than one major gene — and/or several modifiers — involved. In some respects these tomato lines have behaved in a manner similar to the cucumber mosaic "resistant" cucumbers studied by Shifriss, Myers and Chupp (10). The work here has not shown, however, whether the heterogeneity noted in the tomato material is primarily genetic, or what portion may be accounted for by testing methods, variations in the virus, appearance of additional viruses in the field, environmental effects, or the interplay of environment and heredity. The implication is apparent that testing of large numbers of plants is desirable if the best combinations are to be obtained at an early time. In most of our individual tests, only 1000 to 3000 plants have been studied.

Data in Tables I and II clearly show that, without question, there is within resistant lines a delay in development of mottling or of distortion of tomato leaves following inoculation with heavy concentrations of the TM virus. Is this "resistance" due to an actual lack of inoculation, to a very slow multiplication of the virus, to masking effects, to slow transport of the virus within plant tissues, or to other factors? Doolittle, Porte and Beacher (2) have shown that certain lines of *Lycopersicon hirsutum* possess high resistance to TM virus; it has been observed by Alexander, Lincoln and Wright (1) and by McFarlane, Hartzler and Frazier (9) that *L. peruvianum* may possess valuable genes for resistance; Holmes (5) showed that *L. pimpinellifolium* tended to resist development of TM virus in the tissues, and that plants performed very satisfactorily in spite of presence of the virus. A tendency toward escape from infection (klendusity) was noted by Holmes (6) in *L. Chilense*. Although *L. Chilense* was not involved in the parentage of these lines, it is possible that such resistance is not peculiar to *L. Chilense* alone. *L. peruvianum* has been considered very closely related to *L. Chilense*.

Since the Hawaii lines have been derived from a complex cross involving *Lycopersicon esculentum*, *L. hirsutum*, *L. peruvianum* and *L. pimpinellifolium*, it is possible that more than one type of resistance may have been secured and maintained from these species. Our effort has been aimed primarily at the attainment of a practical breeding objective; it has not been feasible to study in detail the behavior of the lines in an attempt to explain their observed behavior with respect to

symptom development. Yet such studies may reveal information of great value to the breeder. Certain of the most promising lines were sent, at an early stage of development, to Dr. F. O. Holmes. His studies on the nature of the material, soon to be published, will no doubt aid in a clarification of the behavior pattern of the lines discussed in this paper.

Summary

Data on resistance to tobacco mosaic virus in advanced generations of progeny from the cross involving *Lycopersicon esculentum*, *L. hirsutum*, *L. peruvianum*, and *L. pimpinellifolium* species are presented. Plants of certain lines exhibit a delay of many weeks in development of TM symptoms. The most resistant lines are plum or cherry type tomatoes. Lines with better horticultural characters possess less resistance, indicating possible need for further hybridization. All lines are highly compatible with *Lycopersicon esculentum*.

Whether the resistance is due to an actual resistance against inoculation, to slow multiplication of the virus, to masking effects, to slow virus transport, to combinations of these, or to other factors has not been determined. Since there is the possibility of involvement of more than one gene and/or gene modifiers, a rather difficult breeding problem may be involved. Dominance of resistance has been high indicating possible ultimate value for use in commercial F_1 hybrid combinations.

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Skin Puncture Studies on Red-Ripe Tomatoes[1]

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THE purpose of conducting skin puncture studies was to provide data whereby any correlations possibly existing between strength of skin and tomato fruit cracking in the field would facilitate future work.

Other specific aims were to note the differences in skin strength between the stem end, the middle and the blossom end of red-ripe tomatoes within variety 222. Also, in a similar test, to obtain data on the strength of skin and the differences in skin strength between red-ripe Rutgers and Gulf State Market tomatoes. As with 222 it was felt that future studies in the field might indicate to what extent, if any, skin strength is correlated with the incidence of cracking.

Frazier (1) found (although he published no data on it) that the skin resistance of the creases radiating from the stem end of the tomato fruit was considerably less than the resistance between the creases or at the flower end when fruits were subjected to puncture tests. He used a corn pressure tester with a piston 0.514 mm in diameter for his studies. Frazier (1) also reported that the older the fruit becomes, the greater is the probability that it will crack. He found that this tendency is especially pronounced up to the time fruits reach red-ripeness.

PROCEDURE

Variety 222:—Seed of variety 222 was obtained from G. Reynard, plant breeder with Campbell Soup Company in Riverton, New Jersey. This variety had shown evidence of some resistance to cracking according to conversations with G. Reynard and H. M. Munger of Cornell University.

Variety 222 also seemed favorable for this study for the following reasons: (a) the plants produced an abundance of fruit in the greenhouse and so provided adequate material for completing the tests, and (b) the fruits ripened evenly, were smooth skinned, round and very uniform in size.

Six plants of 222 were grown in soil in the greenhouse in 8-inch pots. Three tomatoes were harvested as they reached the red-ripe stage. The tomatoes were cut from the cluster in order to avoid possible tearing of the skin due to pulling the fruit from the plant. Only uncracked fruits were used in these tests. Each tomato was tested within 2 hours from the time of harvest.

Fig. 1 illustrates in diagrammatic form the apparatus designed to measure the force necessary to puncture the skin of red-ripe tomatoes. A tomato was placed on an inverted jar lid on platform 2 to keep the fruit immobile while pressure was being applied. A 100–cc beaker

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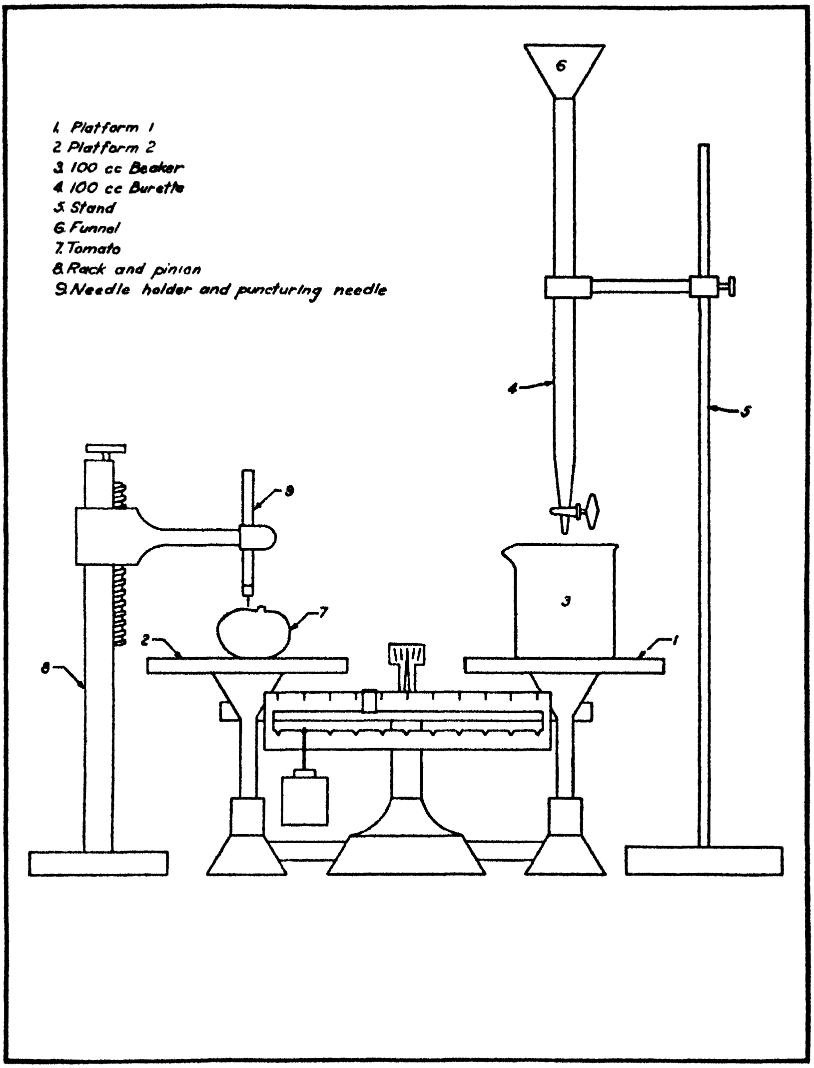

FIG. 1. Apparatus designed to measure the force necessary to puncture the skin of red-ripe tomatoes.

was placed on platform 1 of the scale which was then balanced. Clamped to a rack and pinion immediately above the tomato was an aluminum needle holder with a platinum wire which protruded $^3/_{16}$ inch below the chuck. The burrs on the edges of the wire had been very slightly filed to avoid uneven cutting of the skin. The area of the puncturing surface was 0.20268 sq mm as determined by a Brown and Sharpe micrometer.

Above the beaker on platform 1 was a 100–cc Geisler burette with a straight stopcock. The burette which was filled with water was held in position by a support stand on a tripod base.

After balancing the scale, a 30-gram weight was placed on platform 1 which was then held in a balanced position while the wire was lowered to the surface of the tomato skin. Platform 1 was released gently placing the 30 grams pressure on the surface of the tomato skin. After releasing platform 1 the water was turned on above the beaker and the moment the wire punctured the tomato skin it was turned off. The 30 grams pressure plus the number of cubic centimeters (grams) of water it required to puncture the skin was then recorded.

Ten readings were taken at the stem end around the edge of a circle approximately 1 inch in diameter. Ten readings were taken halfway between the stem and the blossom ends, and 10 punctures were made at the blossom end within an area of a circle approximately 1 inch in diameter.

Upon completion of these tests each figure was converted to grams per square millimeter necessary to puncture the skin. This was accomplished by multiplying each recording by 4.934.

Rutgers and Gulf State Market:—In another preliminary test eight plants of each variety were used, but only one fruit was harvested from each plant. The method employed in testing skin strength of these two varieties was the same as that outlined for variety 222 above. (Punctures were made with the same wire and all figures were converted to grams per square millimeter by multiplying by the same factor, 4.934.)

Results and Discussion

Table I shows the effect on resistance to puncture of three locations on the fruit. The differences between the strength of skin at the stem end, the middle and the blossom ends were the most highly significant differences noted in these tests. This is a point of interest with regard to tomato fruit cracking in that Frazier (1) reported that both radial and concentric cracking occurred mostly at the stem end. It appears probable, therefore, that further study and work in breeding tomatoes for more uniform skin strength, and tomatoes with stronger skins, is justified.

Table I shows the effect of plants on resistance of the tomato skins to puncture. The figures represent the average value of 90 readings taken on three fruits from each plant. The fact that plants varied so significantly is not too surprising in the light of Frazier and Bowers' (2) observations on tomato fruit cracking. They have observed that "severity varies greatly in different years, with soils, varieties, vines of a given variety, fruits on a vine, or even fruits on a cluster".

Table I shows a significant interaction between different plants and locations on the fruit. Here again the results obtained by the puncture tests appear to parallel Frazier and Bowers' (2) observations regarding the unpredictable behavior of fruits with regard to the incidence of tomato fruit cracking.

Table I also shows that fruits within plants vary significantly at the

TABLE I—AVERAGE SKIN PUNCTURE READINGS IN GRAMS PER SQUARE MILLIMETER FOR VARIETY 222

Plant	Location				
	Fruit	Stem	Middle	Blossom	Average
1	1	270	191	434	298
	2	228	246	386	287
	3	319	342	381	347
Average		273	260	400	311†
2	1	333	494	449	425
	2	321	433	475	410
	3	319	442	474	412
Average		324	456	466	415
3	1	233	343	388	321
	2	273	335	377	328
	3	229	238	418	295
Average		245	305	394	315
4	1	409	389	414	404
	2	378	373	460	404
	3	352	383	444	393
Average		380	381	439	400
5	1	346	385	517	416
	2	320	320	437	359
	3	342	343	465	383
Average		336	349	473	386
6	1	446	428	458	444
	2	412	436	406	418
	3	352	441	480	424
Average		403	435	448	429
Average of all readings		327*	365	437	

Least difference for significance:

	5 Per Cent Level	1 Per Cent Level
*Locations on fruit	24	32
†Plants	39	55

All interactions are significant at the 1 per cent level.

one per cent level and that the interactions of fruits and locations on the fruit within plants are also significant at the 1 per cent level.

Rutgers and Gulf State Market:—The average skin strength, or resistance to puncture, was greater, but not significantly so, for the eight Rutgers tomatoes tested than it was for Gulf State Market. The averages for plants (they might be called averages for fruits since only one fruit was tested for each plant) show reversals in Table II. This large variation within varieties probably accounts for the fact that there was no significant difference. It is recognized, also, that a very small sample was studied.

Table II shows that the location on the fruit effect is significant at the 1 per cent level. In both Rutgers and Gulf State Market the stem end is the least resistant to puncture, the middle next and the blossom end most resistant to puncture. This is noted also in Table I for 222, and it would appear safe to say that this is probably the case in most of our tomato varieties. Once again, there is evidence, though not enough, that with cracking occurring most frequently at the stem end, as reported by Frazier (1), a correlation might well exist between strength of skin and tomato fruit cracking.

TABLE II—AVERAGE SKIN PUNCTURE READINGS IN GRAMS PER SQUARE MILLIMETER FOR GULF STATE MARKET AND RUTGERS VARIETIES

Variety	Location	Plants								
		1	2	3	4	5	6	7	8	Average
Gulf State Market	Stem	273	189	273	152	388	184	155	163	222*
	Middle	347	267	329	184	309	285	216	245	273
	Blossom	381	302	452	207	450	427	310	362	361
	Average	333†	253	352	181	382	299	227	257	
Rutgers	Stem	349	260	335	307	311	198	297	348	301
	Middle	312	210	224	331	365	361	285	411	312
	Blossom	303	264	313	296	516	575	483	466	402
	Average	321†	245	290	311	397	378	355	408	

Least difference for significance:

	5 Per Cent Level	1 Per Cent Level
*Locations on fruits within varieties	64	87
†Plants within varieties	26	35

The interaction of plants and locations on fruit within varieties is significant at the 1 per cent level.

Table II shows that the plants (or the fruits, as explained above) varied significantly at the 1 per cent level within varieties. This, too, was found with 222 as can be seen in Table I and may account in part for the difference in cracking observed within some of our tomato varieties as Frazier and Bowers (2) have reported.

Table II shows the interactions between plants and locations within varieties. These were significant at the 1 per cent level. It will be noted here that there are several reversals in skin strength between locations in both Rutgers and Gulf State Market.

SUMMARY

Puncture data were obtained on three red-ripe tomato fruits from each of six plants within variety 222. These data show that the stem end of the ripe fruit was significantly less resistant to puncture by the method employed than was the middle of the fruit and that resistance to puncture at the middle was significantly less than at the blossom end of the fruit. There were some reversals, however, as indicated by significant interactions. Plants varied significantly in their resistance to puncture. On some of the plants fruits varied significantly from each other.

A limited test on Gulf State Market and Rutgers tomatoes indicated that the stem end was significantly less resistant to puncture than was the blossom end. Within both of these varieties plants varied significantly. The interaction was significant between plants and locations on the fruit.

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The Effect of Storage Upon the Ascorbic Acid Content of Tomatoes Harvested at Different Stages of Maturity[1]

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TOMATOES produced for the fresh market are harvested at various stages of maturity, ranging from the "green-mature" crop of the distant shipper, to the "red-ripe" fruit harvested by the local truck gardener. Similarly the time elapsed between harvest and the consumption may be only a few hours or may be many days. The effect of these factors upon the ascorbic acid content of the tomato has not been precisely defined in the literature.

In the earlier work on the ascorbic acid content of tomatoes Jones and Nelson (4) and Clow and Marlott (1), using bio-assay methods, found an apparent increase in vitamin C associated with maturation of the fruit. The latter workers (1) state that fruit ripened off the vine seemed to be as effective a source of the vitamin as vine-ripened fruit. MacLinn and Fellers (7) and MacLinn, Fellers, and Buck (8) found no difference in ascorbic acid content due to maturity and no loss in ascorbic acid from ripe fruits which were stored for 10 days at room temperature. Brown and Moser (2) found higher values in overripe than in firm ripe fruit and showed no effect of temperature or length of storage period upon the ascorbic acid content of ripe tomatoes. Murphy (10) has shown a significantly higher value for ripe tomatoes but Kaski, Webster and Kirch (5) and Wokes and Organ (11) found no difference in content of green and ripe fruits harvested at the same time.

Wokes and Organ (11) also found that tomatoes harvested while green and ripened at room temperature in sunlight developed an ascorbic acid content similar to that of vine-ripened fruit, but if ripened in the dark at room temperature the content was appreciably lower. Other workers have not indicated the light conditions accompanying experimental storage periods. Murneek *et al* (9) state that greenhouse tomatoes picked "green" are relatively low in ascorbic acid content but upon ripening at room temperature reach a value almost equal to that of vine-ripened fruit. However, field-grown tomatoes often showed the highest content during the early stages of maturity, and fruit harvested while green seemed to lose ascorbic acid upon ripening.

Hamner, Bernstein, and Maynard (3) stored green mature tomatoes at 65, 70, 75, 80, and 90 degrees F, analyzing the ripened fruits at the end of 1, 2, and 3 weeks. Two week's storage at the three lower temperatures did not appreciably affect the ascorbic acid content, but at the end of 3 weeks at 65, 70, and 75 degrees F; or after 2 weeks at 80 or 90 degrees F, there was a marked decrease. These workers also found a slight increase with maturity of the fruit. Kays (6) reported a remarkably uniform loss of ascorbic acid from tomatoes in storage.

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Those held on ice retained 70 per cent and those uniced 62 per cent of initial content after 6 days storage.

Materials and Methods

Rutgers tomatoes grown at the University Plant Research Farm were used in these studies. Fruit harvested on August 3 and 17 were classified into six categories of maturity, namely 1, immature green; 2, mature green; 3, breaking color; 4, pink; 5, mostly red or firm ripe; and 6, red or canning ripe. Random lots from classes 1, 2, and 3 were stored at 70 degrees F. Lots from class 4 were stored at 50 degrees F. Lots from classes 5 and 6 were stored at 35 and 50 degrees F. Each lot consisted of from 2 to 4 half bushel baskets. All lots were placed in storage within 4 hours after harvest. The storage rooms were unlighted except for brief intervals during sampling.

Samples of each maturity were obtained for ascorbic acid analysis at the time of harvest, and additional samples were taken from each lot during storage at 2-day intervals up to 10 days. At each sampling date, the tomatoes in classes 1 and 2 which were ripening during storage, were sorted into three maturity classes, (a) green, (b) breaking color, and (c) pink or riper. The percentage falling into each class was determined and the classes analyzed separately.

Samples for ascorbic acid estimation consisted of eight fruits selected at random from each lot. Pie-shaped segments from opposite sides of each tomato, weighing in total 50 grams were blended for 3 minutes with 250 ml of 0.4 per cent oxalic acid in a Waring blendor. After filtering, an aliquot of the extract was titrated visually with standardized indophenol dye solution.

Results

The data from both harvests at each sampling date are given in Table I and the variance analysis summary of these data in Table II. In com-

TABLE I—The Ascorbic Acid Content, During Storage, of Tomatoes Harvested at Different Stages of Maturity

Maturity Class At Harvest	Temperature of Storage (Degrees F)	Harvest Date	Ascorbic Acid (Mg/100 Gm) After Storage of: 0 Days	2 Days	4 Days	6 Days	8 Days	10 Days	Treatment Means
1. Green	70	Aug 3	12.1	9.3	11.3	9.9	7.8	9.3	9.9
		Aug 17	17.8	15.4	15.3	10 5	15.5	12.2	14.5
2. Mature green	70	Aug 3	13.2	11.8	14.3	9.9	11.8	12.5	12.2
		Aug 17	21.0	14.8	18.5	13.6	12.3	15.7	16.0
3 Breaking	70	Aug 3	14.7	13.5	15.7	14.9	13.0	13.3	14.2
		Aug 17	21.3	16.5	18.3	17.1	16.0	19.6	18.2
4. Pink	50	Aug 3	14.1	12.1	14.4	11.5	9.5	9.5	11.8
		Aug 17	22 5	17.0	17.3	14.5	16.3	15.5	17 2
5. Mostly red (firm ripe)	35	Aug 3	16.2	14.3	14.7	11.6	12 7	11.5	13.4
		Aug 17	22.9	15.8	16.0	13.8	13.3	12.9	15.8
5. Mostly red (firm ripe)	50	Aug 3	16 2	14.0	13.6	13.5	12.5	13.0	13.8
		Aug 17	22 0	16.1	16.7	16.1	16.1	16.4	17.4
6. Red (canning ripe)	35	Aug 3	19.0	14.7	15.8	13.8	13.0	13.5	14.8
		Aug 17	18 8	15.8	19.2	10.5	13.6	15.1	15.6
6. Red (canning ripe)	50	Aug 3	19.0	14.9	15.7	10.7	13.8	15.2	14.6
		Aug 17	18.8	14.3	16.4	12.7	14.8	14.2	15.4
Storage means: Harvest		Aug 3	15.6	13.1	14.4	12.0	11.8	12.1	13.2
Harvest		Aug 17	20.7	15.7	17.2	13.6	14.8	15.3	16.2

L.S.D. (5 per cent level): Between treatment (maturity-temperature) means: 1.6.
Between storage means: 1.4.

TABLE II—VARIANCE ANALYSIS OF DATA IN TABLE I (ASCORBIC ACID CONTENT OF TOMATOES DURING STORAGE)

Variance due to:	Degrees of Freedom	Mean square	F.
Storage period	5	64.55	34.89**
Treatments (maturity and temp.)	7	17.04	9.21**
Harvest date	1	225.40	121.84**
Interaction:			
(a) storage by treatment	35	1.72	.93
(b) storage by harvest	5	5.38	2.91*
(c) treatment by harvest.	7	9.14	4.94**
Error variance	31	1.85	

**Significant at 1 per cent level.
*Significant at 5 per cent level.

piling the data for treatments 1 and 2 in which the fruit was divided into maturity classes before analysis, the analytical results were weighted according to the percentage of fruits falling into each class at each sampling period in order to obtain a single value for the treatment.

The tomatoes harvested on August 17 were significantly higher in ascorbic acid than those harvested August 3 with one exception, that of the ripest maturity class. Ascorbic acid content increased with maturity of the fruit at time of harvest on both dates, again with the excepion of the ripest class harvested August 17. This increase due to maturity was more pronounced in the earlier harvest when the "immature green" fruit contained 12.1 as compared with the 19.0 mg per 100 grams content of the "red ripe" tomatoes. The mean value for the "immature green" class was significantly lower than that of any other treatment. Tomatoes harvested at the "breaking" stage and stored at 70 degrees F showed the highest mean ascorbic acid value for the entire storage period, and had the greatest retention during storage.

In all treatments there was a decrease in ascorbic acid content during storage. This decrease occurred largely during the first part of the storage period. There was no significant difference in the content of the riper maturity classes stored at 35 and 50 degrees F.

The ascorbic acid readings on the tomatoes of classes 1 and 2 in which analyses were made on the different maturity grades when removed from storage, are given in Table III. Although these data are from more limited sampling lots and are not amenable to statistical analyses, there are present certain indications concerning ascorbic acid

TABLE III—THE ASCORBIC ACID CONTENTS OF TOMATOES RIPENING DURING STORAGE AT 70 DEGREES (HARVESTED BEFORE INCEPTION OF COLORATION)

Stage of Maturity When Analyzed	Ascorbic Acid (Mg/100 Gm) After Storage of:						Average
	0 Days	2 Days	4 Days	6 Days	8 Days	10 Days	
(Harvested Aug 3)							
Green	12.7	10.3	12.7	9.3	7.3	8.9	10 2
Breaking color.	—	12.3	12 8	9.7	9.6	11.5	11.2
Pink or riper.	—	—	18.4	13.7	13.0	11.2	14.1
(Harvested Aug 17)							
Green	10 4	15.3	15.0	11.0	12.5	11.4	14.3
Breaking color.	—	12.8	22.4	13.3	12.2	14.1	15.0
Pink or riper.	—	—	—	16.8	18.8	16.5	17.4

changes in fruit ripening during storage. The fruit analyzed before inception of coloration gave lower readings as the length of storage increased. These lower values may represent actual loss of ascorbic acid during storage or may be a function of a lower initial content in these more immature fruit. The highest ascorbic acid values found, almost without exception, in the samples which showed some coloration, strongly suggest an increase in ascorbic acid content associated with pigment formation. However, it will be noted that the ascorbic acid content of the fruit ripening during storage was appreciably lower than that of vine-ripened tomatoes at the time of harvest.

SUMMARY

The ascorbic acid content of Rutgers tomatoes was found to increase slightly with increasing maturity of the fruit at the time of harvest. There was a loss of ascorbic acid during storage of "green mature" tomatoes at 70 degrees F and during storage of riper fruit at 35 and 50 degrees F. Analyses, during storage, of tomatoes harvested in the green stage, showed an apparent increase in ascorbic acid associated with coloration of the fruit. Tomatoes ripened in storage did not attain the ascorbic acid value of vine-ripened fruit.

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Calcium and Potassium Relationships in Tomatoes and Spinach[1]

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Although calcium has been shown to have a marked effect on the growth of the tomato plant under controlled conditions, the influence of lime on the yield of fruit under field conditions has not been consistent. Thompson (7) and Jones and Rosa (4) cited investigations in Texas, New Jersey, Virginia, West Virginia, Missouri, New York and Rhode Island which indicated that lime was of no benefit to tomatoes. More recent observations by Hester (2) however, indicate that tomatoes may be benefited by lime. In addition, Sayre (6) reported a marked benefit to the crop on an acid soil from the use of 3 tons of dolomitic limestone per acre. In this report an attempt is made to indicate possible causes for the lack of response to lime reported for the tomato crop; and to determine how spinach, a plant that responds markedly to lime, differs from the tomato in its ability to accumulate calcium and potassium.

Materials and Methods

A field experiment was conducted in Schenectady County, New York, on a Hoosick loamy course sand on plots that had been treated two years previously with coarse magnesium limestone at rates of 0, 1, 2, and 4 tons per acre, and with cow manure at rates of 0, 7.5, 15, and 30 tons per acre. The pH values of the soil on the unlimed plots ranged from 5.2 to 5.5, and of soil from plots that had received lime at the rate of 4 tons per acre, ranged from 5.9 to 6.6. The lime and manure had been applied in such a manner that each rate of liming was used with each rate of manure application, resulting in 16 treatments. Before setting the tomato plants a uniform application of a 5-10-5 fertilizer was applied to the area at the rate of 1,000 pounds per acre. Six weeks after the plants were set, and 2 weeks before the first picking, additional potash as muriate of potash, at the rate of 60 pounds per acre of K_2O was applied as a side dressing to one-half of each plot. Total yields were low due to a prolonged drouth during the last 6 weeks of the harvest season. In addition to yield data, foliage samples were taken for ash analysis from the terminal growth of the plants at the time of the final harvest.

In a second experiment, Marglobe tomato and Virginia Savoy spinach plants, after attaining suitable size to make transplanting feasible, were transferred from soil to an aerated nutrient solution of the composition suggested by Hoagland and Arnon (3). After the plants had become adjusted to their new environment the compositions of the cultures were altered as indicated in Table III. In addition to

[1]Journal Number 1101 of the Michigan State Agricultural Experiment Station.

This material has been taken in part from a thesis presented in 1940 for the Ph.D. degree at Cornell University, where the study was conducted under the direction of Dr. H. C. Thompson.

the changes in the Ca and K ions, the attainment of the large quantity of Ca ions in the high calcium cultures necessitated the addition of 2,553 ppm of Cl ions. In all other respects the nutrient contents of the solutions were the same. Dry weight determinations were made after the plants had been allowed to grow for 2 weeks in the solutions and the dried material was ashed and analyzed for CaO, K_2O and MgO.

Results and Discussion

The results of these investigations are shown in Tables I, II and III. In the field experiment (Table I) neither lime at 4 tons per acre, with the 50-pound potash application, nor the additional potash application (60 pounds per acre) on the unlimed areas had any significant effect on the yield of tomatoes on the non-manured plots. However, on the area receiving 4 tons of lime, additional potash significantly increased the yield by 2.5 tons to the acre. Also the yield for the 4-ton lime application was increased bv 2.2 tons to the acre over that of the unlimed plot when the comparable plots received the application of 110 pounds of potash to the acre. Neither lime nor a 110-pound application of potash was significantly better than either no-lime or a 50-pound application of potash where either treatment was applied independently of the other to the non-manured areas.

On the unlimed area, the data (Table I) indicate that an additional

TABLE I—Influence of Potash, Lime and Residual Manure on the Yield of Tomators (Yield Expressed in Tons to the Acre)

Manure (Tons Per Acre)	K_2O (Pounds Per Acre)	Limestone (Tons Per Acre)				Difference 4 0
		0	1	2	4	
	110	7.7	9 5	9.8	9.9	2 2
0	50	7.4	7.2	8 3	7.4	0.0
	Difference	0 3	2.3	1.5	2 5	2.2
	110	7 4	9.0	10.3	10.7	3.3
7.5	50	7 9	7 9	8 7	9 8	1 9
	Difference	0 5	1.1	1.6	0.9	1.4
	110	9.2	9 3	10.6	11 6	2.4
15.0	50	9 0	9.0	10 0	9.8	0 8
	Difference	0.2	0 3	0.6	1.8	1.6
	110	10 4	10.0	11.0	12.3	1.9
30 0	50	8.7	9.4	10 5	11 0	2.3
	Difference	1.7	0.6	0.5	1.3	-0.4
Difference (30 0)	110	2.7	0.5	1.2	2.4	-0 3
Difference (30–0)	50	1.3	2.2	2 2	3.6	2.3
	Difference	1.4	-1.7	-1.0	-1.2	

Least significant difference 5 per cent—0.8 tons; 1 per cent—1.2 tons.

application of potash significantly increased yield 1.7 tons to the acre on areas that had received 30 tons of manure per acre, but was without significant effect on lightly manured or non-manured areas. It is interesting to note that at the 50-pound potash application, the heavy rate of manuring was responsible for an increase in yield of only 1.3 tons to the acre while at the higher rate of potash application, the heavy rate of manuring resulted in an increase in yield of 2.7 tons to the acre. It would appear that on a light soil either liming or manuring

increases the effectiveness of potash fertilization. When all three factors were at the maximum, namely, lime 4 tons, manure 30 tons, and potash 110 pounds to the acre, the maximum increase of 4.9 tons to the acre was realized.

A study of the influence of treatment on the CaO and K_2O contents (Table II) of the plant tissue may offer some explanation for the yield

TABLE II—INFLUENCE OF POTASH, LIME AND RESIDUAL MANURE ON THE K_2O AND CaO CONTENT OF TOMATO FOLIAGE (EXPRESSED AS PER CENT OF THE DRY WEIGHT)

Manure (Tons)	K_2O (Lbs)	0 Lime		1 Lime		2 Lime		4 Lime	
		K_2O	CaO	K_2O	CaO	K_2O	CaO	K_2O	CaO
0	110	5.2	2.9	5.4	3.5	4.4	3.3	3.5	4.2
	50	3.8	5.2	4.0	4.6	3.6	3.7	3.4	4.0
7.5	110	5.4	3.4	5.0	4.1	5.1	3.5	5.4	3.4
	50	4.6	3.9	4.8	3.6	4.4	3.6	4.4	4.5
15.0	110	5.5	3.0	6.6	3.8	5.7	3.6	5.7	4.3
	50	5.7	3.6	6.6	3.0	4.9	3.4	4.8	3.6
30.0	110	6.8	3.5	6.7	4.2	6.5	3.6	4.8	5.0
	50	6.1	3.5	7.0	3.6	5.4	4.0	5.6	3.9

Least significant difference 5 per cent—0.75 per cent; 1 per cent—1.07 per cent.

behavior. On the unlimed, non-manured area, increasing the potash content from 50 to 110 pounds per acre drastically altered the CaO and K_2O contents of the plant. The highest (5.2 per cent) CaO content in the foliage from any plot was found in plants from this unlimed area which received the 50-pound potash application, and also the lowest (2.9 per cent) with the 110-pound potash application, a difference of 2.3 per cent. Also the greatest change in the potash content (1.4 per cent) for the additional potash application was found in the foliage of plants from the unlimed, non-manured area. These wide differences in composition are not related to differences in growth and consequently to the total quantity removed; and in addition, neither the relationship of high K_2O–low CaO, nor of low K_2O–high CaO are associated with high yields.

On the non-manured, limed soils the CaO content in the plant is lowered with the 50-pound-per-acre potash fertilization and increased with the 110-pound-per-acre potash fertilization, indicating that lime produces a stabilizing effect on CaO absorption. Liming also prevented the high potash application from resulting in an excessive accumulation of potash in the plant.

The residual effect of manure, which might be comparable to the effect of organic matter, facilitated the accumulation of potash by the plant without depressing the CaO accumulation (Table II). Perhaps the increase in the organic matter content from the manure helped to maintain the applied potash in a more available form. This agrees with Wander and Gourley (8) who found that the mulching of tree fruit resulted in an increase in the percentage of potash in the foliage.

On the basis of the influence of treatment on composition, it would appear that the yield differences resulting from treatment are associ-

ated with the ability of both lime and manure to partially regulate or affect a balance in the absorption of CaO and K_2O. Lime tends to prevent the excessive absorption of potash and at the same time stabilizes its own absorption. The effect of the residual manure facilitates the absorption of potash, while at the same time tends to maintain the CaO absorption of the plant.

A chemical analysis of tomato and spinach plants from the second experiment grown in solutions of identical chemical composition (Table III) showed that the tomato plant produced the greatest quantity of

TABLE III—INFLUENCE OF THE CONCENTRATION OF CALCIUM AND POTASSIUM IN SOLUTION CULTURES ON THE COMPOSITION OF TOMATO AND SPINACH PLANTS (VALUES ARE AVERAGES OF FOUR CULTURES EACH CONTAINING FOUR PLANTS)

Concentration (Ppm)	Dry Weight (Gms Per Plant)	K_2O (Per Cent)	CaO (Per Cent)	MgO (Per Cent)	Fe (Per Cent)	K_2O/CaO
			Tomato Foliage			
254Ca— 57K	8.23	4.05	3.54	0.98	0.012	1.17
208Ca—141K	7.82	6.36	3.52	1.04	0.013	2.23
160Ca—235K	11.15	7.82	3.48	1.08	0.014	2.23
1698Ca— 47K	5.98	5.31	5.79	0.73	0.012	0.87
1648Ca—141K	6.36	7.59	5.42	0.89	0.012	1.41
1600Ca—235K	5.26	9.86	4.71	0.61	0.015	2.10
			Spinach Entire Plant			
254Ca— 47K	1.63	7.55	1.89	2.13	0.211	4.07
208Ca—141K	2.30	11.32	1.78	1.79	0.166	6.35
160Ca—235K	2.95	15.20	1.36	1.59	0.206	10.82
1698Ca— 47K	1.73	8.04	4.20	1.54	0.197	1.89
1648Ca—141K	2.81	10.85	3.16	1.16	0.140	3.30
1600Ca—235K	3.30	11.48	3.81	1.08	0.140	2.93

dry matter in cultures that were low in calcium, and that the spinach plant produced the greatest quantity of dry weight in cultures that were high in calcium. However, tomato plants grown in any culture had a higher concentration of CaO and a lower concentration of K_2O, MgO and iron than spinach grown in the comparable solution.

In the (160 Ca-235 K) solutions, tomato plants contained more than twice as much CaO as did spinach plants, and spinach plants in turn contained approximately twice as much potassium as did tomato plants. The reduction in growth of the tomato in the (1600 Ca-235 K) solution as compared to that obtained at the other levels of potassium, may be associated with the low content of MgO found in plants that were grown in this solution. Iron content of spinach plants is approximately ten times that of tomato plants in this experiment. The ratios of K_2O/CaO indicate that increasing the concentration of calcium in the culture solution had a more marked effect in lowering the ratio in spinach than in the tomato.

The work of Collander (1) in water cultures and of Newton (5) in soil showed that different species growing under identical conditions vary widely in their ability to accumulate particular cations. This selective ability of different species to absorb cations is apparently unrelated to the requirement of spinach and tomato. It is possible that this phenomenon in some cases might be the result of an initial difficulty experienced by some plants in their native habitats of ap-

propriating certain ions due to a low concentration of the particular ion in the soil.

It might be hypothecated that the tomato during its evolution grew under conditions in which calcium was difficult and potassium was easy to absorb and that consequently those plants of the species survived that had a mechanism that allows for excessive calcium absorption when the cation was abundantly available and potassium was relatively low in the soil. This hypothesis would help to explain a lack of response of the plant to lime when potassium is somewhat limiting. Spinach on the contrary might have evolved on a soil in which potassium was the more difficult of the two ions to appropriate and consequently requires a considerable quantity of calcium (lime) to prevent or balance its remarkable ability to appropriate potassium. In practice, increasing quantities of potash fertilizer become economically profitable on tomatoes when the lime content of the soil is increased; while on the other hand, potash responses in spinach are seldom observed except on well-limed soil of low potash content.

Conclusions

The results indicate that large applications of lime to an acid soil (pH 5.3), low in exchangeable potassium and calcium were of no benefit to tomatoes. However, if lime was applied in conjunction with increased amounts of potassium fertilizers, highly significant increases in yield resulted. The influence of residual manure was found to be comparable to that of potassium fertilizers. The benefit arising from the residual manure might be related to its ability to keep potassium from being fixed by preventing fluctuations in the soil moisture.

In comparing the CaO and K_2O absorption of spinach and tomato plants, the results indicated that spinach differed from the tomato in that it was able to absorb larger quantities of potassium from solutions with a relatively low concentration of potassium. The possibility is suggested that the tomato may be classed as a plant requiring a relatively greater potassium concentration in the soil solution in relation to the calcium concentration than spinach or than other plants that have a low calcium content.

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Transposition of Green and Dry Weights of English Peas[1]

By W. S. Flory, Jr., *The Blandy Experimental Farm, University of Virginia, Boyce, Va.*

In a breeding and varietal study with English peas *(Pisum sativum)* it was often found desirable to know what a certain vine-dry weight of peas, saved for seed, would have been if lots had been harvested at the prime green-ripe eating stage, and *vice-versa.* The present study had for its objective the estimating of index figures or percentages which might be used with approximate accuracy in transposing green-ripe and vine-mature picked weights in certain English pea lines.

Materials and Methods

Three varieties were used in the field work. These were selections of Roger's Winner (our accession number P 202), of a cold hardy Progress type (P 196), and of Creole (P 135). The peas were grown together in garden rows at College Station, Texas in May and June 1942. A similar planting was grown in the same months of 1943 of the P 202 line, the 1943 plants being grown from the same seed lot as were the 1942 P 202 plants. Three samples of 10 friuts each were picked at the green-ripe stage, from plantings of each variety. Weights, to the nearest milligram, were secured shortly after harvest for each individual fruit, and then after shelling, for the seeds and also for the pods, independently, of each fruit. Since the possibility, if not the probability, existed that the weights of the green-ripe fruits might equal — upon drying — the weights which would have resulted from vine maturity of these same fruits, the pods and seeds of each fruit harvested at the green eating stage were thoroughly dried. Following this the dry weights of seeds and pods were secured, again for each fruit. At the time of harvest of the green fruits, every picked fruit of each variety was paired with another fruit of the same variety which, as accurately as could be approximated, was identical with the original fruit in seed number, size and weight. The paired fruits of the second lot were each tagged, numbered and left to vine-dry. When these had matured, or "vine-dried", they were removed and weighed as were the original lots.

In Table I are presented the total number of peas per sample, and the average per individual pod, for the peas picked in prime green-ripe eating condition, and also for the paired pods left to ripen and dry on the vine. The paired and similar pods, left on the vines, would presumably have had green weights closely approximating those of the pods picked in green condition. Likewise, one is apparently justified in assuming that the weights of the paired and similar pods left to mature on the vine approximate the weights that would have occurred

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Appreciative acknowledgment is made of the aid of Mr. J. Howard Ellison in the securing of the 1942 weights, and of Dr. Boyd Harshbarger for having the variance analysis carried out.

TABLE I—NUMBER OF SEEDS IN PODS OF PAIRED FRUITS BY SAMPLES

Line Number and Sample	Fruits Picked Green	Fruits Paired and Left to Vine-Mature
P 202		
1	55	52
2	59	53
3	58	61
Total	172	166
Average	5.73	5.53
P 196		
1	64	66
2	54	52
3	48	54
Total	166	172
Average	5.53	5.73
P 135		
1	61	60
2	69	71
3	59	57
Total	189	188
Average	6.3	6.27

under similar conditions for the pods actually picked in the green-ripe stage. While some variations in weights would have occurred for the two lots of peas, had they been weighed at comparable stages, the liklihood is that such variations would have been slight. Some of the discussion of results is premised on an assumption of close similarity in weights between the two lots at their several stages of maturity.

RESULTS AND DISCUSSION

Total of weights secured in 1942, to the nearest hundredth of a gram, are presented in Table II, where each sample weight represents the sum of the weights of the 10 pods in that sample. Total weights for the 30 fruits of each variety, as well as the average weights for each fruit, are also indicated in this table — for each of the lines used. Weights are shown for: (a) green-ripe fruits, (b) for these same fruits after drying, and (c) for the paired fruits, following natural vine-maturity or "vine-drying". It may be noted that the total weights of the vine-dried fruits are higher and the seed weights of these are considerably higher, than for the green-dried ones. The pod weights are less for the vine-dried, than for the green-dried fruits.

An analysis of variance of the 1942 data involved a consideration of the three varieties, of three replications (or samples) and of two treatments — green-drying and vine-drying. This analysis shows the suspected differences both as between lines and treatments to be significant at the 1 per cent level. The green-dry weights, therefore, are quite different from vine-dry weights, and could not be used in accurately transposing from green-ripe weights to approximate vine-mature weights. The lesser loss in weight of seeds and somewhat greater loss in pods, of vine-dried as compared with green-dried peas, could probably be traced to a transfer or transposition of materials from pod (and also probably from vine) to seed in the process of natural maturity. In the analysis of variance the treatment-line inter-

TABLE II—COMPARISON OF GREEN AND DRY WEIGHTS (IN GRAMS) OF ENGLISH PEAS

Line Number and Sample	Green			Green-Dried*			Vine-Dried**		
	Total	Seeds	Pod	Total	Seeds	Pod	Total	Seeds	Pod
Roger's Winner									
P 202									
1	24.17	13.50	10.63	5.52	3.84	1.68	7.00	5.80	1.20
2	27.10	15.00	12.10	5.64	3.68	1.96	8.59	6.86	1.73
3	29.05	15 45	13.59	5.60	3.80	1.80	6 56	5.24	1 32
Total	80.32	43.95	36.32	16 76	11.32	5.44	22.15	17 90	4.25
Average†	2.68	1.47	1.21	0 56	0.38	0.18	0.74	0.60	0.14
Progress									
P 196									
1	98 78	39 42	59.36	16 08	8 08	8.00	24.48	18.67	5.81
2	92.76	43.41	49.36	15 74	8.40	7.34	18.54	13.04	5 50
3	85.16	33 58	51 58	16.89	9.32	7 58	19.03	13.70	5.33
Total	276.70	116 41	160 30	48 71	25.80	22.92	62.05	45.41	16.64
Average†	9.22	3.88	5.34	1 62	0.86	0 76	2 07	1.51	0.56
Creole									
P 135									
1	28.28	14.74	13.54	5.80	2.98	2 82	9 96	8 00	1 96
2	43.81	24.36	19.45	9.24	6.22	3.02	11 04	8.56	2.47
3	36.26	17.64	18.62	7.26	3.77	3 48	9 58	7.36	2.23
Total	108.35	56.74	51.61	22.30	12 97	9.32	30.58	23.92	6.66
Average†	3.61	1.89	1.72	0.74	0.43	0.31	1.02	0.80	0.22

*These weights were taken on the same pods and seeds as were those in the three preceding columns, but were secured after the green pods and seeds had been thoroughly dried

**These weights were secured from fruits matched, as nearly as possible, for size and seed number with the fruits whose weights are recorded in the preceding columns The fruits weighed here were left on the vines until thoroughly mature and dry.

†These average weights are for individual fruits, pods, or the seeds from individual pods, as the case may be. Since each sample was composed of ten fruits, these average weights are based on thirty fruits in each case.

action was not significant in the case of total weights of fruits, nor in the case of seeds alone. In the case of pods alone, however, this interaction was significant at the 1 per cent level, which indicates that when the lines do not act comparably with respect to fruit weight following the two methods of drying, this difference in response is due chiefly to differences in pod behaviour in the several lines.

In Table III the per cents of total weight represented by both seeds and pods are shown for each variety when the fruits are in green-ripe condition, in green-dried form and also when in vine-dried maturity. In the Progress (P 196) line the seeds represent a somewhat smaller proportion of the total weight in each case, than is true for the other

TABLE III—PER CENTS OF TOTAL FRUIT WEIGHT REPRESENTED BY SEEDS AND BY PODS (BASED ON THREE SAMPLES OF TEN FRUITS EACH)

Line	Green		Green-Dried		Vine-Dried	
	Seeds	Pods	Seeds	Pods	Seeds	Pods
P 202	54.7	45.3	67.5	32.5	80.8	19.2
P 196	42.1	57.9	53 0	47.0	73.2	26.8
P 135	53.2	46.8	58.4	41.6	78.3	21.7
All three lines	46.7	53 3	57.1	42.9	76.0	24.0

two varieties. In general, however, there is considerable consistency with respect to the three varieties for any given stage of maturity. The average per cents of weight of seed and pod have been determined for the three varieties combined, and these figures are presented in the bottom line of the table. From these percentages it may be seen that, considering the three varieties together, in green-ripe peas the weights of seeds and of pods are roughly equal (about 50: 50, or 1 : 1); in green-dried peas weights of seeds make up, roughly, three-fifths of the total weight (60: 40, or 3: 2); and in vine-dried peas seeds comprise about three-fourths, and pods only one-fourth of the total weight (75: 25 or 3: 1).

Table IV presents data for each of the varieties with respect to loss in weight, and the per cent loss in weight, both from the drying of fruits picked in the green-ripe stage and following vine-maturity of the paired fruits. Data is presented both with respect to weight, and

TABLE IV—WEIGHT, LOSS IN WEIGHT AND PER CENT LOSS IN WEIGHT FOLLOWING ARTIFICIAL AND NATURAL DRYING (BASED ON THREE SAMPLES OF TEN FRUITS EACH)

Line	Weight (Grams)			Loss in Weight (Grams)		Per Cent Loss in Weight	
	Green	Green-Dried	Vine-Dried	Green-Dried	Vine-Dried	Green-Dried	Vine-Dried
				Total Fruits			
P 202	80.32	16 76	22.15	63 56	58 17	79 16	72 43
P 196	276 70	48 71	62.05	227 99	214 65	82.40	77.58
P 135	108.35	22 30	30 58	86.05	77 77	79.42	71 78
Total	465 37			377.60	350.59	81.17	75 33
				Pods			
P 202	36.32	5 44	4 25	30 88	32.07	85.02	88.30
P 196	160.30	22 92	16.64	137.38	143.66	85.70	89 62
P 135	51 61	9.32	6.66	42.29	44 95	81.94	87.10
Total	248.23			210.55	220.68	84.82	88.90
				Seeds			
P 202	43.95	11 32	17.90	32.63	26.05	74.22	59.27
P 196	116 41	25 80	45.41	90.61	71 00	77.84	60.99
P 135	56 74	12.97	23.92	43.77	32.82	77 14	57.84
Total	217.10			167.01	129.87	76.93	59.82

loss of weight, for fruits and for seeds alone and for pods alone. The per cents of loss were quite close for the three varieties, for a given method of drying, but were slightly greater in each case for Progress, which always had larger and more succulent pods than either of the other two varieties. The averages in the table may be roughly rounded, and the per cents of weight losses following green-drying and vine-drying, respectively, are about as follows: fruits — 80 and 75; seeds — 75 and 60; and pods — 85 and 90. These figures again indicate the greater loss in weight of pods following vine-drying, while total weight loss is greater following green-drying and seed weight loss is considerably greater after green-drying. Some of this difference in total loss may have been due to errors in pod pairing, but the majority of it probably represents an actual difference in weight loss.

In 1943 the experiment was repeated with Roger's Winner (P 202) but not with the other varieties. Sample size, pairing of pods left to vine mature, weighings, and drying all corresponded with the 1942 procedure. The results are presented in Table V and when compared with the data for P 202 in Table II the 1942 and 1943 weights are found to be quite similar.

TABLE V—COMPARISON OF GREEN AND DRY WEIGHTS (IN GRAMS) OF ROGER'S WINNER (P 202) ENGLISH PEAS—1943 (EACH SAMPLE BASED ON TEN FRUITS)

Green			Green-Dried			Vine-Dried		
Total	Seeds	Pod	Total	Seeds	Pod	Total	Seeds	Pod
29.36	15.94	13.42	5.90	4.00	1.90	8.88	7.03	1.85
26.59	14.70	11.89	5.45	3.57	1.88	7.45	5.66	1.79
28.62	15.48	13.14	5.35	3.62	1.73	8.44	6.38	2.06
84.57*	46.12	38.45	16.70	11.19	5.51	24.77	19.07	5.70
2.82**	1.54	1.28	0.56	0.37	0.18	0.83	0.64	0.19

*Total weights for all three samples presented in this line
**Average weights per fruit given in this line.

Other data, not presented here, have shown that both weight losses by vine maturity, and also respective weights of pods and seeds, are quite different for peas grown in the greenhouse, than for field grown ones.

SUMMARY AND CONCLUSION

The finding of most importance from the standpoint of the original objective concerns proportional weight loss between the prime green-ripe and the vine-mature stages. For the varieties worked with and the field conditions under which they were grown, the weight lost by green fruits on vine-drying was rather uniform between lines, as well as between samples within the same line. In the case of Roger's Winner, the only line on which this experiment was carried out in the field for 2 years, the weight losses were quite comparable between years. In the experiment with these three varieties it was found that field grown peas, matured on the vine for seed, had about one-fourth of the total green-ripe fruit weight, while vine-dried seeds had about two-fifths, and pods only about one-tenth of the respective green-ripe weights. Closer approximation could be made of course by applying individual line data. Proportional weight losses will likely need to be determined by additional sampling for lines and environments which exhibit appreciable variation from those involved in this experiment. Exactness of the data required will be a determining factor here.

The general method would seem adaptive for use with several crops, especially with those usually harvested for use in a green-ripe condition, such as green beans, lima beans or sweet corn. The simple procedure may be used in securing approximate data which it is sometimes desirable to have but is often unavailable.

Tissue Analysis in Diagnosis of Nutritional Troubles[1]

By E. M. Emmert, *University of Kentucky, Lexington, Ky.*

Work Before 1940

The idea of analyzing the plant is old and dates back to DeSaussure and Leibig, but the idea of testing the conducting tissues of the plant was first used in a non-quantitative way by Hoffer in 1926 when he tested corn for nitrates by diphenylamine. Some of the first quantitative tests were made in our greenhouses and laboratory head house at Lexington, Kentucky in 1930 when we used the phenoldisulfonic acid method for nitrates in tissues and animonaphtholsulfonic acid for phosphates. In 1939, Thornton enlarged on Dr. Hoffer's ideas and developed what is known as the Purdue quick tests. These tests were still only semi-quantitative, expressing results as low, medium and high. They have been improved since then but we will not take up details on methods here.

In 1934, the Kentucky Experiment Station published Circular 43 which described tissue tests which enabled the expressing of results as parts per million of green tissue, but which were quite rapid and could be performed in the field.

In 1938, Carolus published the Virginia Truck Crop Station Bulletin 98. This gave a full description of methods used in Virginia on truck crops; these were adaptations of the quantitative methods used in Kentucky and the soil tests of Morgan.

Carolus shows outstanding correlation between the tissue tests and the application of fertilizer. Yields are also highly correlated with tissue test results. His results show that tissue tests magnify deficiencies and make them easily detectable. Even rather small deficiencies can be detected without the use of a colorimeter. Carolus gives the parts per million of nutrients in normal vegetable crops during rapid growth, but does not show the critical levels needed at the various stages of growth.

He finds the range of soluble nitrogen for potatoes to be 972 to 2000 ppm, and for tomatoes to be 905 to 1540 ppm.

Total Analyses

So far, we have been talking of analysis of the stem tissues of the plant for nutrients in the soluble form only. For many years total analyses of the plant have been made mostly with the purpose of determining the nutritional value for humans and for stock. However, some investigators are using total analyses as an indicator of what the plant is getting from the soil.

These analyses necessarily are a summation of nutrients already used in the anabolic process to make plant tissue and of nutrients in solution coming from the soil. Environment influences the metabolic processes and are reflected in these analyses. Of course, environment

[1]Presented at the round table discussion on nutritional troubles at Cincinnati, September 8, 1948.

influences soluble nutrients in the tissues at the time of the analyses, but total analyses are a summation of the effects of environment throughout the life of the plant. It seems that analysis for soluble nutrients are much more directly tied up with the amount the plant can actually get from the soil.

Perhaps the outstanding workers in this field are Thomas and Mack who have advocated the Foliar Diagnosis system.

Nutrient intensity = sum of the percentages of N, K_2O and P_2O_5

Nutrient quality = the percentage the N, K_2O and P_2O_5 is of the total milliequivalents of nutrients

The range of variations in total percentages is small compared to the ranges of soluble nutrients found in petioles.

The long procedures used to find these small variations do not lend to practical applications as do the more rapid tests on the petioles of plants. Furthermore, the analysis of the flow of nutrients through the main stems and petioles is a more direct indicator of the ability of the soil to furnish the needed nutrients.

Nevertheless valuable results have been worked out by investigators using total analyses and they should be used to aid the more versatile petiole methods used in practical applications.

It seems that total analyses may be of particular value in the diagnosis of perennial plants, especially trees, while tissue analysis for soluble nutrients is of especial value for annual plants.

In making the tests it seems best not to go to either extreme as to methods used. The use of semi-quick tests which enable relatively accurate analyses expressed as parts per million seem better than either the rapid qualitative tests or the long total analyses; that is, as far as vegetables are concerned. Vegetables have relatively narrow ranges of nutrients at the various growth stages at which they do best and methods should be used which will detect these critical ranges quite accurately, but rapidly enough to enable sufficient data to be collected.

Work After 1940

1941:—In 1941, Ulrich, working in the sugar beet fields of California, used the quick dephenylamine test on the petioles of beet leaves. He found he could tell when plenty of nitrogen was present and when it was deficient.

When the tests showed:

1. Nitrate in large and small center leaves the supply was adequate.
2. Nitrate in large leaves only; barely adequate.
3. None in either; a serious deficiency existed.
4. In small center leaves only; a new supply was being absorbed.

In 1941 and 1942, Carolus and Wolz using the semi-quick quantitative tests found that sidedressing P increased P in potato petioles more than plowing it down or surface drilling. High nitrogen increased P absorption but lowered yields despite high soluble N content. This was during a period of drouth and likely would not have happened with plenty of moisture.

Green manure plus fertilizer slightly increased yields and nutrient

content. Their results show that high nitrogen just before bloom reduced yields of potatoes.

In 1941, the California Cotton Experiment Station, cooperating with Dr. Ulrich used the semi-quick quantitative methods on potatoes and found 3 to 4 weeks after emergence that below 800 ppm caused yields of 140 sacks (100 pounds) per acre while over 1000 ppm gave yields of over 300 sacks per acre.

1942:—Lorenz working with potatoes at the same station added ammonium sulfate at the rate of 250, 500, 750, and 1000 pounds per acre.

Lbs. N	*Ppm N*	*Yield Sack per Acre*
0	324	233
250	849	382
500	1296	412
750	1301	425
1000	1404	382

He also tested Uramon against $(NH_4)_2SO_4$ and found by the tissue tests that $(NH_4)_2SO_4$ gave 1132 ppm against 1107 ppm for Uramon. The yield for sulfate was 393 sacks while Uramon gave 363 sacks.

Head Lettuce

Lorenz also used tissue tests on head lettuce. He found that the critical period was just before heading. The critical level seemed to be 400 ppm for nitrate and 75 to 100 ppm for phosphate. K was always in excess.

Later N applications did not increase yield much but was valuable in producing dark, green heads.

In another test on lettuce in the Salinas Valley of California, fertilizer increased nitrogen in the tissues but did not increase P or K. Lorenz had five times as much P and eight times as much K as Carolus had in lettuce grown in Virginia. This explains why he did not get much increase in P and K in the tissues nor increases in yield.

Potatoes

In a test in Kern County Lorenz made some tissue tests at two stages of growth. The nutrients did not go over 1223 ppm in the early stages, so the highest yield occurred here, although a high yield was also obtained at 984 ppm. Where the nitrogen went below 100 ppm in the late stages the yields were much lower. This indicates that maintaining nitrogen in the late stages is important.

Grapes

While we are not dealing with fruits it is interesting to note that Ulrich found recently matured leaf petioles of grapes were the best indicators of nitrogen nutrition and also that nitrate nitrogen was better than total nitrogen.

1943:—In this year, Dr. Ulrich published a paper entitled "Plant Analysis as a diagnostic Procedure". Here, he introduces the concept of critical concentrations.

These concentrations are found in three ways:

1. By analysis of fertilized and unfertilized crops in the field and correlating with yields over many locations.
2. By varying amounts of nutrients and measuring yields in pots or solution cultures.
3. By analyzing plants showing visible deficiencies.

By these methods the critical concentrations for each nutrient and each crop may be established. He shows that the critical concentration of K is not varied much by time or other nutrients. He does not show so much constancy for N and P, and it is likely they will not be as constant as K. I will show later that the critical concentrations will also vary with the stage of growth.

The final conclusion of Dr. Ulrich is that analysis of the plant in conjunction with a comparison to the critical nutrient range, permits conclusions regarding the nutrient level in the soil, better than analysis of the soil itself.

Shear working with tobacco at Blacksburg, Virginia, used tissue tests for four years in comparison with soil tests and came to the conclusion that tissue tests were better than soils tests in determining availability to tobacco.

Carolus and Wolz used starter solutions on tomatoes and got no increases. Tissue tests showed no increases in nutrients and explained why no response was obtained.

Scarseth has made extensive use of the quick Purdue tests on corn. His tests are semi-quantitative without crushing, emulsifying or extracting. He found that tissue tests take the guess work out of ferilizer research since just applying fertilizer may not raise levels in the plant. In one case, plowed under P raised the level while drilled P did not, due to drouth. He finds that tissue tests show need long before visual deficiencies appear.

1944:—Lorenz again working with tissue tests on potatoes found good correlation between application and the levels in the plant. He is quite definite in stating that less than 800 ppm of nitrogen, 1 month after emergence depresses yields.

1945:—In fertilizer studies on potatoes at Ithaca, Smith and Kelly ran tissue tests in connection with placement tests. The correlation of N content of petioles and yields was highly significant.

1200 pounds 5-10-10 gave 650 ppm, 291 bushels
2400 pounds 5-10-10 gave 936 ppm, 343 bushels

In all cases one-half of the fertilizer in bands and one-half broadcast gave the highest nitrogen in the petioles and the highest yields. P and K were high in the tissues at all times and gave no yield differences. Magnesium, however, was limiting and tissue tests for Mg correlated with yields quite well.

1946:—Ulrich did some further work on beets. He determined critical levels for beets on a dry weight basis. These tests on the dry weight basis are long and not as suitable for actual practical application as are tests on the green weight basis.

Hester working with tomatoes at the Campbell Soup Company, at

Riverton, New Jersey, uses tissue tests in connection with soil tests. He used a sodium acetate extracting solution in a Waring blender.

Uses Brucine, on extract for nitrate – N

Finds: 25 to 50 ppm poor (not as high as phenoldisulfonic method
100 to 200 ppm fair 800 poor
300 to 500 ppm good 1000 ppm good)
600 to 800 ppm too high

Uses stannous oxalate for P
4 to 20 ppm poor
40 to 80 ppm fair same as aminonaphtholsulfonic acid
120 to 200 ppm good
300 to 400 ppm high

Uses turbidity test for K
470 to 990 poor
2600 fair same as cobaltinitrite phenoldisulfonic
4400 good colorimetric method
6000 high

At an Extension conference at Berkeley, California, Lorenz reports the critical nitrate nitrogen level for potatoes as 800 ppm, 5 weeks after emergence in leaf petioles of the third youngest leaves; 30 ppm was the critical level for P in potatoes; 200 ppm was the critical nitrate level for lettuce and celery. In summary, he states that plant tissue tests have been found very reliable and valuable as an aid in the interpretation of fertilizer experiments.

Review of Work on Determining Curves of Critical Need

It seems one critical level is not enough, but that requirements vary considerably at various stages of growth. Studies were made at the Lexington main station and at the Princeton substation at different stages of growth as to which levels of N, P, and K produced the highest yields, and curves of critical need were plotted. When the curve of critical need has been determined then tissue tests can be used to determine whether the levels at any growth stage are above or below the critical levels.

However, the critical level for a particular crop at a particular stage of growth is dependent on several factors and may be expressed as follows:

Critical level = function of soil texture, soil moisture, other nutrients, humidity, temperature cultural practices, length of day, light intensity, variety, and other minor factors.

The curves that have been made have been made for a standard variety during average weather conditions existing at the normal season in May, June and July, with effort made to have no deficiencies other than of the nutrients being studied and with no adverse soil texture conditions. Standard cultural practices were used. No data were used if serious drouth occurred.

If conditions are markedly different from the normal then the level of critical need varies considerably from the one determined. However,

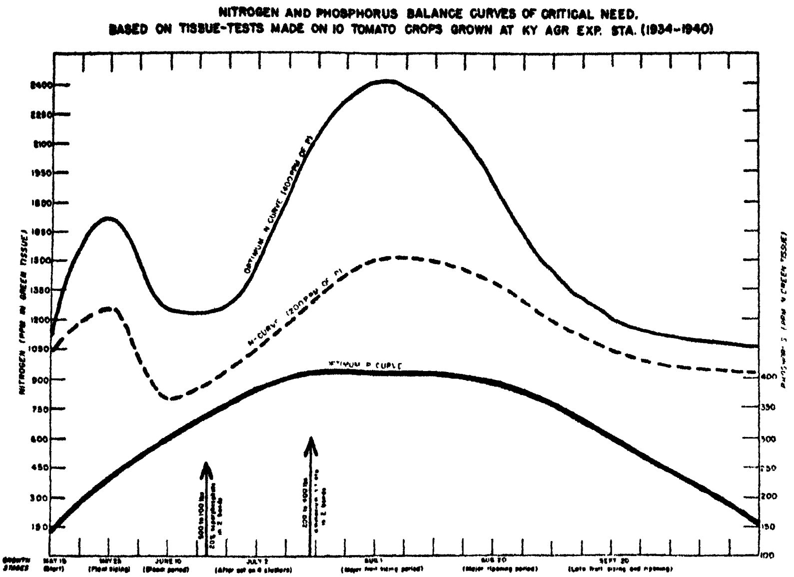

FIG. 1. The curve of critical need of tomatoes for nitrogen and phosphorus at the various stages of growth.

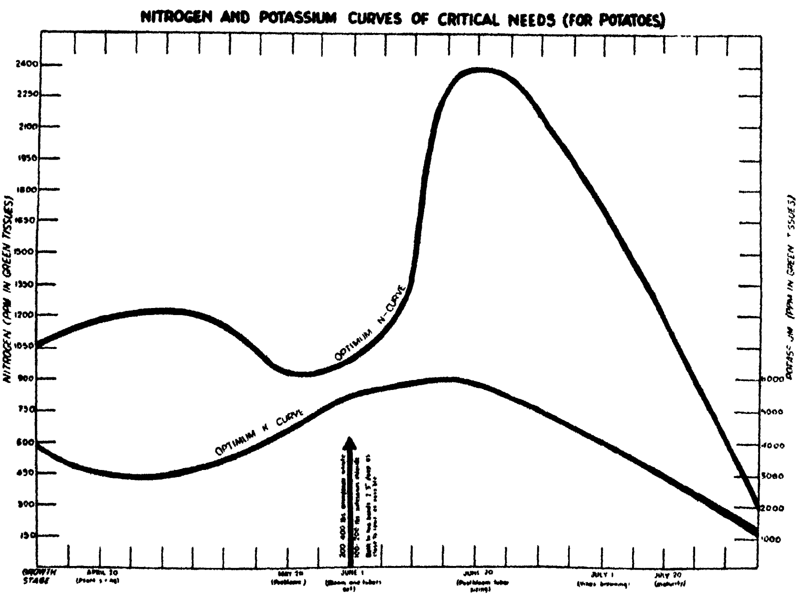

FIG. 2. The curve of critical need of potatoes for nitrogen and potassium at the various stages of growth.

it is usually apparent which way the level will vary, and it is not hard to approximate the variations in level, which the variations from the normal will make.

Two curves of critical need have been determined. The data for the one on tomatoes has been published in Bulletin 430, of the Kentucky Agricultural Experiment Station, in 1942. These are the results from six seasons and 10 crops of tomatoes.

The data for potatoes is just off the press as Kentucky Bulletin No. 529. These two curves are shown in the graphs, Fig. 1 being for tomatoes, Fig. 2 for potatoes.

After this review had been prepared the author received a copy of "Plant Analysis-Methods and Interpretation of Results", which was prepared by Dr. Ulrich as a chapter for the American Potash Institute's new book called "Diagnostic Techniques". In this book Dr. Ulrich gives a comprehensive bibliography and an even more comprehensive discussion of methods and interpretations. Anyone interested in plant analysis should read this chapter when it becomes available from The American Potash Institute, 1155 Sixteenth Street, N. W., Washington 6, D. C.

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Effect of Irrigation on the Production of Carrot Seed

By JOHN H. MACGILLIVRAY and L. J. CLEMENTE, *University of California, Davis, Calif.*

THE following study was made as the result of a widespread interest in vegetable seed production in the years 1942 to 1945. Production studies of several crops were undertaken, with irrigation one of the factors studied in California. The effect of irrigation on onion seed production (5) has already been reported. The reader is referred to the onion paper for complete details of an experimental procedure similar to that used in the carrot seed project.

An examination of the literature on carrot seed production disclosed several studies on general production practices, but none on the effect of irrigation on seed production. Borthwick (1) made an extensive study of carrot seed in relation to germination. He found that the first or primary umbel on the plant produced the highest germinating seed. He pointed out that since there were few primary umbels they did not contribute much to the total weight of seed per plant. Borthwick also pointed out that immature embryos were a cause of low germination, although many of these seed would germinate if they remained in the germinator for several months. Ellis (2) found that carrots with a low soluble solids content survived better in a field planting than those with high soluble solids. Enzie (3), Woodbury (7), and Watkins (6) studied some of the cultural operations of their regions in producing carrot seed. Knight and Blodgett (4) give the various diseases which attack the carrot seed root and offer their recommendations for control. Woodbury and Schultz (8) were able to produce several plants from one root, and suggested the usefulness of this method in a breeding program.

METHODS

Roots of the Imperator variety were obtained from seed companies for planting. These roots were not less than ¾ inch and not more than 1½ inches in diameter at the crown. Roots were planted at the same time as in surrounding commercial fields. The plantings occurred as follows: February 19, 1945, December 19, 1945, and January 11, 1947. Single roots were spaced 30 inches apart each way. There were 96 roots per plot or an area of $^{1}/_{72}$ acre. Three treatments of four replications each were used. The treatments were as follows: A-plots received no irrigation water—the only water available was winter rain stored in the soil; B-plots received an ample amount of irrigation water; and C-plots received about half the water that was applied to the B treatment. At the time these roots were planted, the soil was moist from winter rains. During these years the July 1 to June 30 rainfall was: 1944–45, a total of 15.4 inches; 1945–46, a total of 15.4 inches; and 1946–47, a total of 12.6 inches. Most of the rain falls during the winter months of November to and including March. There is little rain during May and the subsequent months. The crop was grown with the usual cultural practices. Soil samples were obtained before and after the irrigations for soil moisture determinations. Irrigations were started

in April on the B treatment and were made about every 3 or 4 weeks. The soil type was a Yolo loam which has been previously described in California publications.

The umbels were harvested when they had turned brown. The primary or first umbel matured sooner than those opening later. Umbels from the guard rows were harvested first, then discarded. The umbels on the plots were cut with hand shears and placed on wire screens for drying. The plots were harvested on the following dates: August 10, 1945; July 5, 1946, and August 15, 1947. The dried umbels were rolled to break them and shatter the seed. The seed and refuse were put through a ½-inch screen to clean out some of the thrash. The seed was run through a seed scarifier to brush off the small hair-like spikes on the seed surfaces. This process was followed by running the seed through a clipper machine to clean out the light seed, hair-like spikes, and dust. The seed was then run over a gravity table to remove more of the light seed.

Results

Yield data were obtained for 3 years. The nonirrigated treatment (A) always produced the smallest amount of seed, and in 2 years this reduction was significantly less. The yields in the last 2 years were well above the average yields of commercial fields, which were usually about 500 pounds per acre. The low yield in 1945 has been attributed to several factors, probably the most important being late planting of the roots and excessive cleaning of the seed through inexperience. Proper procedures for threshing small samples were more satisfactorily worked out for the last two years.

The slightly heavier 1947 yield might have been due to heavier rainfall in the late spring of 1947, even though the seasonal total was low. In other irrigation experiments the nonirrigated plots have tended to mature sooner, particularly if the crop was a vegetative part of the plant. Carrot seed (non irrigated) tended slightly toward earliness in the 1945 and 1946 crops. This statement is based on observation. On June 13, 1947 the number of center umbels which had turned brown were counted. These percentages were: A-treatment, 26.3; B-treatment, 12.9; and C-treatment, 17.4.

Carrot seed roots removed soil moisture from the 5- to 6-foot soil zone in 1947. In earlier tests samples were not taken below the 4-foot zone. Both onion and carrot seed crops root considerably deeper than onion and carrot crops grown for food or the fresh market.

Data concerning the effect of irrigation on size of seed were erratic. Perhaps the procedures used in the last two years were more accurately developed. In these years the wet treatment produced the largest seed, although the differences were not significant. These results were somewhat similar to those obtained for onion seed (5).

Germination of carrot seed is an important problem of the seed trade since some seed lots are low in germination. The relation of immature embryos to this problem has been previously considered (1). When the germination of these seed lots were obtained a few months after harvest, there were no significant differences in germination. However,

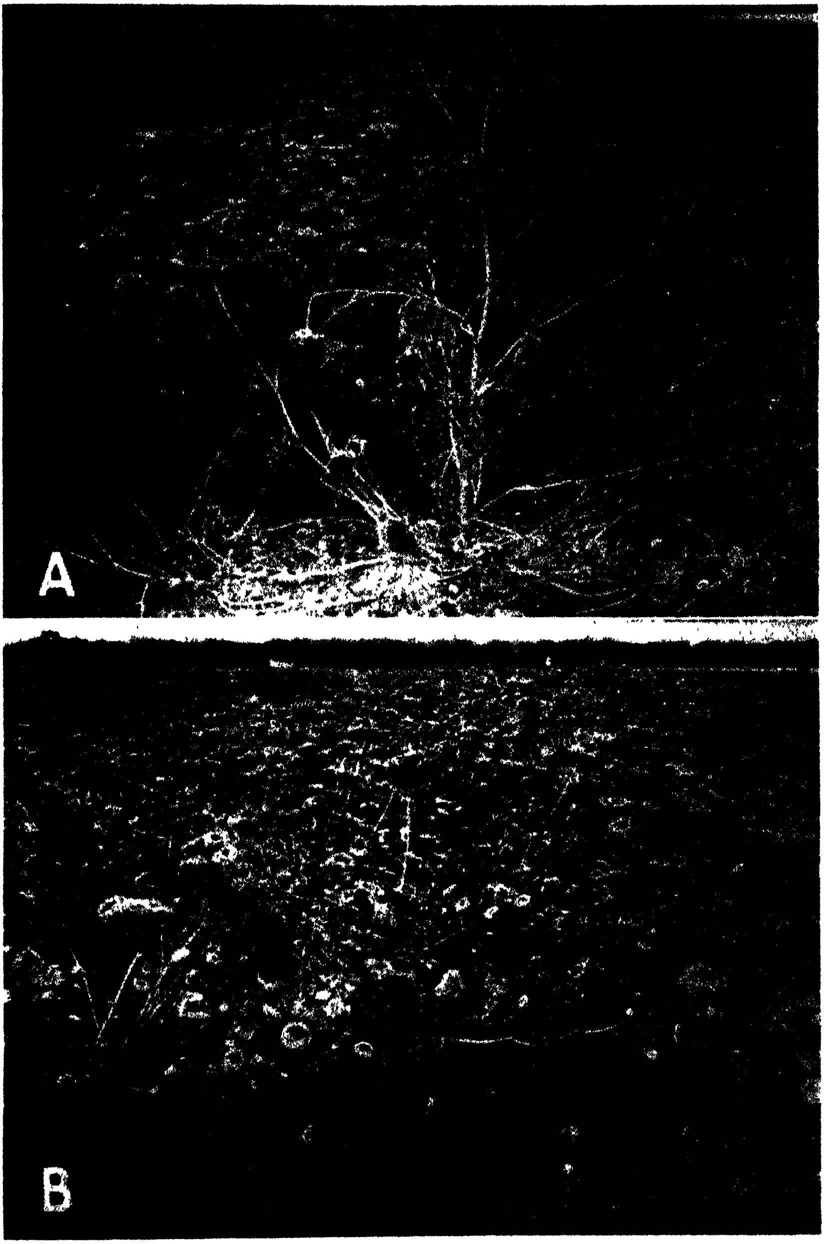

FIG. 1. Considerably more plant growth (B treatment, 12 inches of water) was made by the irrigated plants compared with the nonirrigated plots (A treatment), 1946.

TABLE I—Effect of Irrigation on Yield, Germination, and Size of Carrot Seed

Treatment	Inches of Water Applied	Number of Irrigations	Pounds of Seed Per Plot	Pounds of Seed Per Acre	Per Cent Germination	Per Cent Germination After Storage*	Weight Per 100 Seed (Grams)
Seed Crop 1945—Four Replications							
A—dry	0.0	0	1.19	139	73.8	72.1	0.1516
B—wet	15.0	5	1.89	221	65.8	58.7	0.1371
C—medium	6.0	2	1.23	144	69.8	64.4	0.1479
Least significant difference, odds 19 to 1			0.31	—	N.S.	6.58	0.0072
Seed Crop 1946—Four Replications							
A—dry	0.0	0	5.18	565	67.8	55.0	0.1224
B—wet	12.0	4	8 04	843	64.5	49.3	0.1304
C—medium	6.0	2	7.26	791	64.4	51.2	0.1244
Least significant difference, odds 19 to 1			1.49	—	N.S	N.S.	N.S.
Seed Crop 1947—Four Replications							
A—dry	0.0	0	7.73	958	62.7	71.7	0.1396
B—wet	15.0	5	8.69	1,077	58.3	60.1	0 1430
C—medium	6.0	2	8.18	1,014	62.5	61.4	0.1367
Least significant difference, odds 19 to 1			N.S.	—	N.S.	N.S.	N.S.

*Storage period = 2 years for 1945 and 1946, 1 year for 1947.

in all 3 years the dry treatment (A) produced seed of the highest percentage of germination, and the wet treatment (B) usually produced the lowest. The seed was stored at ordinary room temperatures with little artificial heat in winter. The seed crops of 1945 and 1946 were stored for 2 years before retesting, and the 1947 crop only 1 year. There was a tendency for stored seed to decrease in germination—and this was particularly noticeable in the 1946 seed—although in the 1947 seed, one year's storage caused a slight increase in germination. Even after storage, there is a slightly greater germination of the nonirrigated seed.

Summary

Irrigation increased the yield of carrot seed grown under climatic conditions at Davis, California. Where sufficient winter rains fill a soil to field capacity to a depth of 6 feet, additional irrigation water of about 8 to 12 inches should be adequate in areas similar to Davis, California. The effect of irrigation on seed germination and size of seed was of minor importance.

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The Effect of Winter Storage on the Carotene Content of Carrot Varieties

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THE CARROT, like the potato, can be stored easily for use as a fresh vegetable during winter and spring. Farm and ranch dwellers in the northern areas of the United States harvest carrots in the fall and store them in root cellars for use from November until May or June. The present series of studies was undertaken to determine some of the factors, including variety differences, that affect the quality of carrots stored for home consumption.

Investigation in 1946 yielded data showing that the carotene content of carrots on a dry-weight basis increased for the first 30 days in winter storage and remained fairly constant thereafter up to 60 days. Literature was reviewed and the results reported (2).

The study reported here was made to determine the effect of storage for a longer time on the carotene content of carrot varieties.

Methods and Materials

The nine groups of carrots, as classified by Babb, Kraus, and Magruder (1) were represented by the following varieties: group 1, French Forcing; group 2, Dutch Horn; group 3, Oxheart; group 4, Chantenay; group 5, Danvers; group 6, Imperator; group 7, Henderson Intermediate; group 8, Long Orange; and group 9, Gurney Coreless (Nantes). These varieties were planted in randomized blocks on June 25, 1947. There were four replicate plots of each variety, making a total of 36 plots.

The roots were harvested October 27, and 12 roots from each plot were analyzed to determine the carotene content. The remaining roots were placed in wooden tubs, covered with air-dry sand, and placed in common storage in an underground root cellar. Roots from each plot were in separate tubs, and the tubs were randomized in the same relative position in the root cellar as were the plots in the field.

The temperature of the root cellar was 40 degrees F when the carrots were placed in storage, and dropped to 32 degrees F about February 9. By April 19, the temperature had risen to 40 degrees, and by May 24 to 44 degrees. The relative humidity was kept above 85 per cent by sprinkling the dirt floor twice a week.

Carotene analyses were made on roots taken from each tub at six dates approximately 5 weeks apart as follows: December 1, 1947; January 5, 1948; February 9; March 15; April 19; and May 24. The roots remained firm all during the test, and many had started growth by May 24.

Methods of sampling and analysis were the same as described in the previous paper (2). All figures for carotene content are reported on a dry-weight basis and were compared by analysis of variance.

Results and Discussion

Table I shows the averages for four replications of each variety at each date of analysis in addition to the mean for each variety and the mean for each storage period. Differences required for significance between means as determined by Fisher's "t" test are also shown.

TABLE I—Carotene in Nine Carrot Varieties During Storage (Mg/100 Grams Dry-Weight)

Storage Period (Weeks)	0	5	10	15	20	25	30	Variety Means
Variety	Mg	Mg	Mg	Mg	Mg	Mg	Mg	Mg
Dutch Horn	89.33*	94.68	106.69	98.29	112.46	112.62	115.31	104.20
French Forcing	76.72	98.10	104.64	97.06	107.99	104.88	95.15	97.79
Chantenay	65.32	79.23	87.92	80.66	95.22	87.62	102.87	85.55
Imperator	58.57	76.26	84.46	91.15	87.65	88.25	86.64	81.85
Gurney Coreless (Nantes)	62.55	75.42	81.87	70.39	81.95	93.37	96.93	80.35
Danvers	64.20	77.62	75.74	78.62	82.90	86.49	86.90	78.92
Oxheart	50.03	65.82	66.78	63.28	83.70	87.26	91.31	72.60
Henderson Intermediate	49.01	62.85	72.72	61.08	74.77	76.05	72.51	67.00
Long Orange	45.10	48.15	64.42	50.80	70.15	62.15	70.92	58.81
Means for storage period	62.31	75.35	82.80	76.81	88.53	88.74	90.95	
Difference required for significance between variety means					1 per cent			7.15
					5 per cent			5.42
Difference required for significance between period means					1 per cent			6.30
					5 per cent			4.78

*Each figure is an average of four replications.

Statistically significant differences were found between varieties, between storage periods, and between replications. The interactions *varieties* by *replications* and *storage periods* by *replications* were also significant. The interaction *varieties* by *storage* periods was not significant at the 5 per cent point.

The statistically significant differences between variety means indicate that the varieties studied differ genetically in their carotene content. This was noted by Platenius (3) in 1934.

Dutch Horn and French Forcing were significantly higher in carotene than the other seven varieties. Chantenay, Imperator, Nantes, and Danvers were not different from each other and were significantly lower than French Forcing and Dutch Horn. Oxheart was lower in carotene than Danvers and statistically the same as Henderson Intermediate. Long Orange was the lowest.

These figures for carotene content are higher than the previous year (2) but the differences among varieties are relatively the same. That is, French Forcing and Dutch Horn are highest, Long Orange the lowest, and the other varieties are between these in the same positions as previously reported (2).

While Dutch Horn was used this year and Scarlet Horn used in the previous test (2), the carotene content of these two varieties from the same group is higher than most other varieties. The Nantes used previously (2) is in the same group as the Gurney Coreless used in this test, and the carotene content is relatively the same.

The statistically significant differences between means for storage periods were caused by an increase in carotene content per 100 gram dry-weight during storage. Except for minor drops in carotene content

of some varieties at 15 weeks, the carotene content on dry-weight basis increased during the first 20 weeks of storage and then remained fairly constant until the experiment was terminated at 30 weeks.

The nonsignificant interaction *varieties by storage periods* indicates that all varieties responded alike during storage; the carotene content of all varieties increased. These results confirm and extend those reported earlier (2). The varieties representing each group remain in the same relative position as to carotene content during growth and during storage.

The data presented here are not entirely in agreement with data presented in a previous paper (2) in which it was shown that carotene increased for the first 30 days of storage and then remained fairly constant. However, as is seen in Table I, the carotene content can fluctuate considerably between short storage periods, but over a long storage period can still show a tendency to increase.

In addition to the major effects discussed above, unknown environmental factors affected the carotene content of the fresh and stored carrots causing statistically significant variation among replications and in the interactions *varieties by replications* and *storage periods by replications*. Such variation would be expected if carotene content were affected by local conditions within the field, such as soil moisture, fertility, and crowding, and by local conditions within the tubs, such as aeration and moisture. The scant literature on environmental effects was noted in an earlier paper (2).

Summary

Dutch Horn and French Forcing varieties were significantly higher in carotene than the seven other varieties tested. In storage the varieties showed a general tendency to increase in carotene content per 100 gram dry-weight up to 20 weeks, then remained fairly constant to 30 weeks, although at 15 weeks the carotene content dropped to the 5-week level, then regained the loss at 20 weeks.

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Changes in Carotenoid Content of Harvested Carrots

By G. L. RYGG, *U. S. Department of Agriculture, Pomona, Calif.*

SINCE the carrot is one of the important sources of carotene, a precursor of vitamin A, it is of value to know something about the behavior of the carotenoid pigments in the harvested roots. Measurement of total carotenoid content has been carried out in connection with a general investigation on the effect of removal of the tops on changes in carrot composition after harvest. The phase of the work on carrots reported in this paper was prompted by repeated observations in earlier work which suggested strongly that the concentration of pigments in young bunching-size carrots increased after harvest. Samples preserved in alcohol for carbohydrate analysis were allowed to accumulate, and in all instances it was observed that carrots stored at room temperature contained more pigment than corresponding carrots preserved at the time of harvest. Samples preserved from lots held in cold storage were sometimes more deeply colored and sometimes not noticeably different from those preserved at the time of harvest.

MATERIALS AND METHODS

Carrots of the Imperator variety were obtained from commercial fields located in Imperial Valley, Coachella Valley, Salinas Valley, and near Pomona, all in California. The age and condition of the crops when the collections were made are shown in Table I. The carrots used

TABLE I—AGE AND MATURITY OF IMPERATOR CARROTS ANALYZED FOR TOTAL CAROTENOIDS

Collection	Date Field Planted	Date of Collection	Condition of Field
1	Aug 1943	Feb 9, 1944	Old; many seedstalks.
2	Sep 1943	Mar 7, 1944	Harvest for bunching in progress, few seedstalks.
3	Oct 1943	Mar 20, 1944	Approaching readiness for harvest.
4	Oct 1943	Apr 24, 1944	Field old; many seedstalks
5	Mar 1944	Jul 7, 1944	Preharvest; some roots, including the sample, were large enough to be harvested.
6	Apr 1944	Aug 17, 1944	Same as 5.
7	Sep 1944	Jan 1, 1945	Preharvest.
8	Sep 1944	Jan 26, 1945	Preharvest.
9	Sep 1944	Apr 12, 1945	Ready for harvest for bunching.
10	Oct 1944	May 1, 1945	Field old; many seedstalks.

in this study were topped at the time of harvest. Each lot consisted of 16 to 30 roots and the weight ranged from 1,422 to 3,488 grams. Single analyses were made for each storage condition in the first four collections; in the others duplicate samples were prepared in all instances and the values given are the average of the two determinations.

The carotenoids were extracted by grinding the tissue with sand in a mixture of petroleum ether and alcohol. The mixture contained 30 per cent petroleum ether at the start of each extraction, but this was increased as the water in the sample was removed. Carotenoids were estimated in a neutral wedge photometer (3, 7) which had been calibrated with Eastman carotene. A few spectroscopic analyses

showed that the increase in total carotenoids was largely accounted for by increases in alpha and beta carotene.

The amount of carotenoid found in the stored lots was calculated to the original fresh weight.

Results

The carotenoid content was found to increase consistently after harvest, with the exception of two lots held at 36 degrees F (Table II). The increase was more rapid at room temperature than at lower temperatures, and relatively old roots gained less after harvest than did younger ones. The least gain occurred in collections 1, 4, and 10. These were from old fields which had a high proportion of plants that had developed seedstalks, but plants with seedstalks were not used in the samples. The other collections were from relatively young crops.

TABLE II—Total Carotenoid Content of Imperator Carrots at Harvest and After Holding Under Various Conditions

Collection	No. Carrots	Fresh Weight of Carrots (Grams)		Length of Storage (Days)	Temperature of Storage (Degrees F)	Total Carotenoid Content		
		Initial	Final			Initial (Mg 100 Gm)	Final* (Mg 100 Gm)	Gain (Per Cent)
1	16	1,491	1,449	21	36	8.4	8.4	0
2	25	2,544	2,407	21	36	7.8	8.7	11 5
3	23	2,538	2,434	21	36	10.7	14.6	7.5
4	20	2,516	2,471	21	36	15.5	15 6	0.6
1	16	1,645	1,503	21, 7†	36, 75†	8 4	8 7	3.6
2	25	2,411	2,125	21, 7	36, 75	7.8	10 0	28.2
3	23	2,429	2,112	21, 7	36, 75	10.7	13.0	21.5
4	20	2,583	2,442	21, 7	36, 75	15.5	16.9	9 0
1	16	1,597	1,516	7	75	8 4	9.1	8.4
2	25	2,712	2,629	7	75	7.8	9.8	25.6
3	23	2,490	2,415	7	75	10.7	11.9	11.2
4	20	2,577	2,570	7	75	15.5	16.8	8.4
5	40	3,488	3,441	5	74	13.9	15 4	10.8
5	40	3,456	3,339	10	74	13 9	16.6	19.4
5	40	3,322	3,147	14	74	13.9	16.6	19.4
6	24	1,894	1,838	5	75	7.4	8.9	20.3
6	24	1,784	1,658	11	75	7.4	10 2	37 8
6	24	1,893	1,654	20	75	7.4	11.3	52 7
6	24	1,861	1,524	30	75	7.4	11.1	50 0
7	30	2,363	2,326	7	72	8.1	9.0	11.1
7	30	2,447	2,391	14	72	8.1	10.4	28.4
8	30	2,409	2,390	7	72	7.7	11 7	52.0
8	30	2,374	2,340	14	72	7.7	12.0	55.8
9	30	1,489	1,480	7	72	12.8	15.6	21.9
9	30	1,422	1,405	12	72	12.8	15.4	20.3
10	30	2,162	2,149	7	73	20.1	21.8	8.5

*Calculated to initial fresh weight basis.
†Twenty-one days at 36 degrees followed by 7 days at 75 degrees.

The most rapid rate of increase in carotenoids occurred during the first few days following harvest (collections 5 to 9, Table II). Aeration appears to be essential for the maximum increase to take place. For example, carrots from collection 8 showed an increase of only 1.4 milligrams per 100 grams in 2 weeks at 72 degrees F when held in a closed container without aeration, as compared with 4.3 milligrams when aerated. Perhaps aeration is the basis for the practice of some growers to withhold irrigation for a period prior to harvest in order to improve the color of the carrots. Miller, Cochran, and Garrison (8) found that good aeration was essential for good color development in carrots grown in Louisiana.

The limitation of the ability of carrots to synthesize carotenoids after harvest to relatively young roots undoubtedly explains why such increases have not been found to be of general occurrence. Smith and Otis (12) noted an increase in a few carrots held in a refrigerator, and Garcia (5) reported small increases in stored carrots. Miller and Covington (9) and Ezell and Wilcox (4) found that the carotene of sweet potatoes increased in storage. Werner (15) found that carotene in stored mature carrots remained constant for a period of several months in cold storage and then gradually decreased. Likewise Langley, Richardson, and Andes (6) found that mature carrots retained the carotene without loss during winter storage. The roots with which Werner and Langley, *et al* worked were mature enough to be harvested for winter storage and therefore comparable in this respect to those used in collections 1, 4, and 10. Brown (2) found consistent increases in carrots stored at an unstated temperature. His results were based on calculation to the dry weight basis, and no allowance was made for losses of solids during the holding period; but his results no doubt are in general valid.

The source of the carotenoids formed in storage is not known. Colorless fluorescent compounds have been observed in leaf tissue and in carrots by Strain (13, 14), in tomatoes by Porter and Zscheile (10), and in carrots and in a considerable number of other tissues by Zechmeister and Sandoval (16, 17). One such compound, phytofluene, has been isolated by Zechmeister and Sandoval (17), who found it to be an unsaturated polyene $C_{40}H_{64}$. It is oily and colorless, but fluoresces strongly in ultraviolet light. It has no provitamin A activity. They found no phytofluene in tissues rich in chlorophyll or in tissues free from carotene, such as potatoes, radishes, and the flesh of apples; but carrots of unstated age and variety contained from 7.3 to 8.3 milligrams per kilo of fresh material (17). The possibility that phytofluene may be a precursor of carotene has been suggested (1, 17). The suggestion has also been made that vitamin A may be a precursor as well as a derivative of carotene (11).

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Some Factors Affecting the Size of Carrot Roots

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When carrot fields are harvested for fresh market in the southwestern United States, all the roots are dug at one time. A large proportion of the roots are culled out in the field because they are too small or too large to bunch. Bunch weights are usually standard and though the number of carrots per bunch may vary widely, six to seven roots of uniform size are preferred. In bunches of this size most of the roots vary between 1 and 1¼ inches in diameter. Any practice which would lead to a more uniform root size would, in effect, increase yield.

Two factors which might affect root size of field grown carrots were studied: the distance between roots, that is, spacing, and the non-uniform germination of seeds in the field.

Spacing

The effect of spacing on root size was examined in a commercial field by removing the tops, carefully mapping the position of the roots, and drawing circles proportional to their diameter. Such a map is shown in Fig. 1. The two rows of this bed were planted with a wide shoe so that the seeds were scattered in a band 5 or 6 inches wide. Spacing of the plants is quite irregular but despite this there is little evident relation between spacing and root size. To get a numerical check, the regression of root diameter on the average distance from the center of each root to the centers of the two closest adjacent roots was calculated for the upper row of roots in Fig. 1. The regression calculated in this way was not significant. In another test, seeds were planted by hand on 2 by 2 inch squares. While many seeds did not germinate, so that spacing was not uniform, the spacing was relatively wide as compared to commercial practice. Here again, the root diameter had little relation to spacing. The size distribution for 42 roots from this planting, graphed in Fig. 2, indicates that, even with wide spacing, great variation in size occurs. The coefficient of variation of root diameter for this sample of 42 carrots was 26 per cent compared to 22 per cent for those roots shown in the upper row of Fig. 1.

While these data indicate that spacing is not a major factor controlling root size under field conditions, it is necessary to avoid planting so thickly that crowded and misshapen roots are formed, or so sparsely that yield is reduced. At the present time, precise spacing of carrots is difficult for the commercial grower because of the low percentage germination of most carrot seed. Some growers are making trial plantings with pelleted seed to obtain more uniform spacing.

Percentage of Germination, Weight, and Amount of Seed Required Per Acre

In respect to spacing, data on percentage germination and seed size are of interest as they determine the variability of the per-acre seed requirement for different seed lots. Percentage of germination and

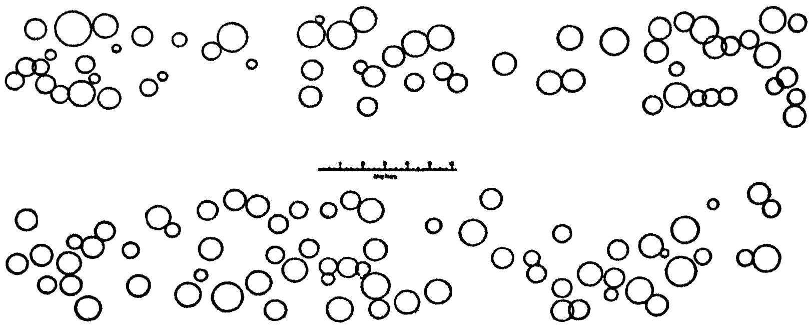

FIG. 1. A map showing the location and diameter of carrot roots planted by the use of a wide shoe. Note that small carrot roots may be located where there is little competition from other roots.

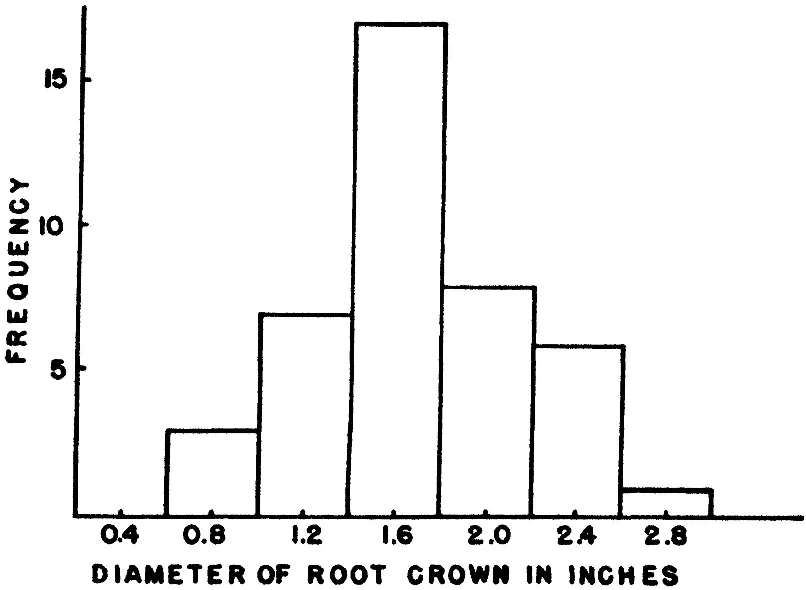

FIG. 2. Frequency distribution of crown diameter of carrot roots. Imperator planted at Davis, California, March 31, and harvested August 9, 1946. All from seedlings emerging between March 29 and April 2. No plants closer than 2 by 2 inch spacing.

number of seeds per ounce were determined for 23 samples of Long Imperator carrot seed from commercial sources. These seeds, in so far as information was available, had been produced in California and Idaho.

Percentage of germination for each sample was determined by germinating four lots of 100 seeds each. Seeds were held, mostly for 14 days, on moist filter paper in petri dishes at 30 degrees C. Counts were made daily.

Number of seeds per ounce, percentage of germination, and pounds of seed required per acre are shown in Table I. The last figure is calculated on the assumption that, under California conditions, 750,000 germinable seeds are required per acre. The range of 1.8 to 4.5 pounds per acre is very great. While the samples with the lowest germination, numbers 6, 18, and 19, show a high poundage requirement per acre, inspection of the table shows that the amount required is equally dependent on the number of seeds per ounce. In fact, the coefficient of variation for seeds per ounce is slightly greater than for percentage germination. If these two variables were associated, that is, if those samples with few seeds per ounce had high germination, these factors would counteract one another, giving a more uniform pounds per acre requirement. Regression of per cent germination on seeds per ounce is positive but the *t* value has odds near 10 to 1 so that the association between high germination and large seeds is very weak. Thus, in some samples, both factors may work in the same direction. Sample 9 has small seeds and high germination, giving a very low per acre requirement, but in sample 4 both conditions are reversed, giving a correspondingly high requirement. For the extremes of the 23 samples examined, equal weights of seed would contain over 2.5 times as many germinable seeds in lot 9 as in lot 4. The above analysis illustrates the range of seed requirement under various conditions of seed size and germination. In actual practice growers usually plant a given number of seeds per foot of row. This automatically takes care of seed size so they only need to adjust their planting rate by percentage of germination.

One point which might cause some trouble in the above analysis is the discrepancy between field and laboratory germination. Data in Table II show that germination in soil flats in a lath house was not significantly different from that on blotting paper in petri dishes. However, commercial conditions are seldom as ideal as this and another test comparing petri dish, flat, and field germination is probably more nearly correct. In this test, six replicates of 100 seeds of Imperator were germinated on each of the three media. Mean germination for

TABLE I—SEED WEIGHT, PERCENTAGE OF GERMINATION, AND POUNDS OF SEED REQUIRED PER ACRE FOR TWENTY THREE COMMERCIAL SAMPLES OF LONG IMPERATOR CARROT SEED

Number	Seeds Per Ounce	Per Cent Germination*	Pounds of Seed Per Acre†	Sample Number	Seeds Per Ounce	Per Cent Germination*	Pounds of Seed Per Acre†
1	21,600	60	3.6	13	26,900	75	2.3
2	18,100	58	4.5	14	21,900	77	2.8
3	18,300	81	3.2	15	16,600	73	3.9
4	17,500	58	4.6	16	20,300	72	3.2
5	25,000	72	2.6	17	16,600	65	4.4
6	25,000	49	3.8	18	20,400	51	4.5
7	18,900	62	4.0	19	22,400	49	4.3
8	22,700	71	2.9	20	26,500	91	2.0
9	31,900	82	1.8	21	22,700	76	2.7
10	19,100	62	4.0	22	19,600	55	4.4
11	29,200	66	2.4	23	20,200	68	3.4
12	24,500	78	2.5	Average	21,600	67	3.3

*L.S.D. 5 per cent; 9.3 per cent; 1 per cent, 12.4 per cent.
†Assuming 750,000 germinable seed needed per acre.

the seed in the field, in soil in flats, and in petri dishes were 47.3 per cent, 51.5 per cent, and 64.8 per cent respectively. The L.S.D. at 5 per cent odds was 8.5 per cent. While field germination of carrots is markedly affected by soil and climatic factors, with some knowledge of the conditions under which the seeds are to be germinated, a fair estimate of field germination could probably be made.

Carrot Seed Germination

The problem of carrot seed germination has received considerable attention. This is partly because field seedings are difficult to bring up, and also because under laboratory conditions, germination is usually poor, variable and slow.

Cole (2) called attention to this slow germination after she found that seeds left in the germinator for 35 to 55 days increased in germination around 12 per cent over the standard 14 day period. Elliot (4) observed continued germination up to 100 days. Borthwick (1) examined seeds which failed to germinate after 14 days and found apparently normal endosperm, but embryos "almost never fully developed and sometimes so small as to be scarcely visible." Flemion and Waterbury (9) and Flemion and Uhlman (7) considered that lack of the embryos, as well as immature embryos, occurred and showed that these conditions, or at least the former, were present in the seeds of the nine species of Umbelliferae studied. Later, these observations were extended to still other species by Flemion and Hendrickson (6).

Heit (10) tried to increase the germination of seed lots by blowing or sieving or a combination of these. He was not able to increase germination significantly, presumably because lack of embryos or undersized embryos have little effect, either on weight or size of seed. In this connection, Dr. J. F. Harrington of this Division furnished us with the following interesting information: 100 soaked carrot seeds weighed 0.2356 grams and 100 embryos removed from soaked seeds weighed 0.0024 grams—about $^1/_{100}$ part of a seed by weight is embryo. This explains the difficulties experienced in separating good from embryoless seed by physical methods. In checking further the effect of seed size, we sieved seeds into five size classes and germinated them under three different conditions. As shown in Table II, there was little practical difference among the size classes. These data on seed size within a sample agree with the conclusion given above that seed size among samples from different sources has little relationship to germination.

Apart from separating out embryoless seeds, or seeds with small embryos, there is a possibility that some type of seed treatment could increase germination. Thus, Durfee (3), examining 84 lots of commercial carrot seed, found an average of 69 per cent germination, 19 per cent embryoless seeds, and 12 per cent "dead" seeds. A similar determination for three lots of carrot seed is shown in Table III. For one lot 16.8 per cent units of the seeds which had embryos did not germinate. The reason why seeds with embryos should fail to germinate is unknown.

TABLE II—Germination of Carrot Seed Separated Into Five Size Classes by Sieving. Germinated on Filter Paper in Petri Dishes, in Soil in Petri Dishes, Both at 30° C., or in Soil in Flats in Lath House (Sample 10, Table I)

Seed Size Classes Diameter of Holes in Screen (Inches)		Per Cent of Total Sample By Weight	Germination (Per Cent)		
Less Than	Greater Than		Petri Dishes, Filter Paper	Petri Dishes, Soil	Flats, Soil
—	1/12	2	54	53	—
1/12	1/14	13	62	56	64
1/14	1/16	26	64	51	60
1/16	1/20	47	60	49	58
1/20	—	12	51	44	52
L. S. D., 5 per cent			9.0 per cent	N.S.	N.S.

TABLE III—Carrot Seed Germination and Per Cent of Seeds With Well Developed Embryos

Sample Number	Per Cent Germination Mean of Eight Lots of 100 Seeds	Per Cent of Seeds With Embryos, Mean of Four Lots of 100 Seeds	Seeds With Embryos But Not Germinating (Per Cent Units)
8	72.0	81.7	9.7
20	86.5	86.5	0.0
18	50 0	66.8	16.8

In an attempt to increase germination, several treatments were tried, such as soaking in hot water (50 to 52 degrees C, 10 minutes), soaking in thiourea (0.1 to 5.0 per cent) and scarifying by cutting or with sulphuric acid (soaking in concentrated acid up to 2 minutes). None of these treatments increased germination over that of untreated seed. If methods of removing embryoless seeds or seeds with smaller than usual embryos cannot be worked out, it seems probable that no seed treatment could be expected to be generally effective, or in any instance, to increase germination very much. If all of those seeds termed "dead" by Durfee could be made to germinate, the average increase, according to her figures, could be only 12 per cent.

Recently Flemion (5) and Flemion, Pool and Olsen (8) have described experiments with Lygus bugs and state that "these results establish that the feeding of Lygus bugs produces embryoless seeds in dill. Preliminary results with carrot are similar". This work is encouraging as it may lead to the production of seed of high germinability.

Non-uniform Germination and Root Size

To determine if early or late germination of seeds within a single planting had any effect on the size of the roots which develop in the field, seedlings were identified as they appeared above ground by applying a small amount of oil paint to one of the cotyledons. All seedlings were painted on a certain date and then after a specified number of days the new crop of seedlings was marked. When the roots reached marketable size, all were dug and the maximum root diameter recorded. Data from three such tests are shown in Table IV. The seeds

in experiments 1 and 2 were planted with a wide shoe that scattered them in a band 5 to 6 inches wide. In experiment 3, the seeds were planted by hand on 2 by 2 inch squares.

Seeds which germinate early may produce relatively large roots because they have more time for growth, or because they place the later germinating seedlings at a competitional disadvantage, either by shading or by the roots which, even in young plants, may extend laterally several inches. The difference in growing time for early and late seedlings is small relative to the total growth period and it seems doubtful that age differences alone could account for the mean size differences for the germination dates within the tests. Also, in experiment 3, where the seeds were widely spaced and competitional effects would be reduced, the size differences were non-significant.

In general, one could conclude from the data of Table IV that non-uniform germination of seeds in the field contributes to the variation

TABLE IV—TIME OF EMERGENCE OF CARROT SEEDLINGS AND DIAMETER OF ROOTS AT HARVEST (IMPERATOR VARIETY)

Experiment Number and Location	Period of Seedling Emergence	Number of Roots in Sample	Mean Root Diameter (Cm)	Significance of Differences in Root Size
Number 1 Soledad, California Harvested July 21, 1945	Prior to March 19 March 20 to 26 March 27 to April 6	56 114 23	3.11 2.74 2.15	Significant at 1 per cent level
Number 2 Davis, Calif. Planted March 3 Harvested August 9, 1946	Prior to April 2 April 3 to 10	200 26	2.50 2.21	Significant at 5 per cent level
Number 3 Davis, Calif. Planted March 14 Harvested August 19, 1946	March 29 to April 2 April 3 to 8 April 9 to 16	45 21 6	4.50 4.21 4.12	Not significant

in root size and that this is associated with competition between early and late germinating seeds rather than simply the age differences among roots at the time of harvest. While spacing among individual roots, *per se* does not seem to be related to root size, thickness of planting will affect overall variation in root size in so far as it controls the competitive effect among seedlings germinating at different times.

The factors which affect non-uniform germination in the field are not known. Perhaps the seed source is important. Fig. 3 shows germination rate graphs for three of the lots listed in Table I. Here lot 23 with a marked germination peak might give more uniform field germination than lot 10. As pointed out earlier, undersize embryos cause delayed germination in laboratory tests. How these react in the field is not known. Elliot (4), germinating seed in soil in the laboratory stated that "very few seeds sprout with sufficient strength to produce a seedling after 14 days." Flemion and Hendrickson (6) note that there seems to be no relation between immature embryos and lack of embryos. Flemion, Pool and Olsen (8) do not discuss the relation of Lygus bugs to immature embryos.

Even with uniform germination, there seems to be a remarkable variation in carrot root size. This is perhaps not surprising as commercial strains of carrots are relatively heterozygous (Welch and

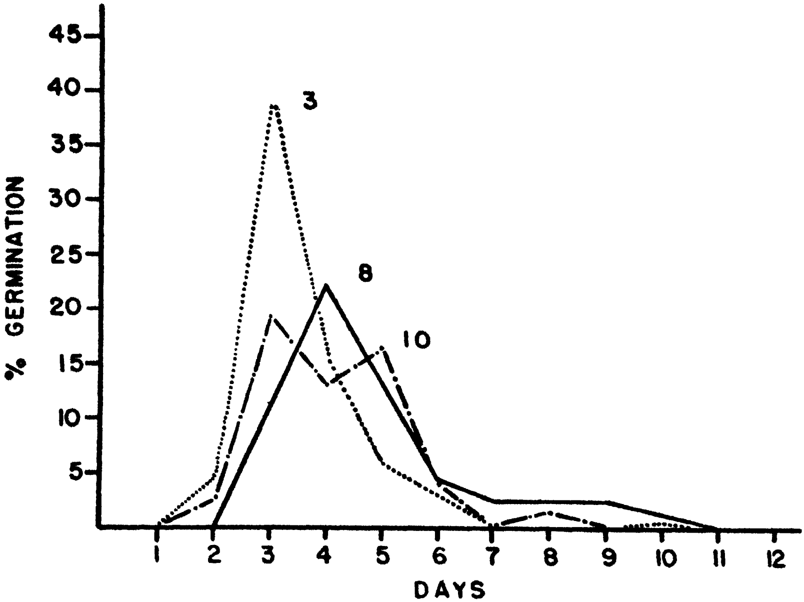

FIG. 3. Per cent of seeds germinating daily on blotting paper in Petri dishes at 30 degrees C, of three of the carrot samples listed in Table I. Selections made to show the marked variation in germination rate among seed samples.

Grimball, 11). The sample of 42 roots discussed earlier, and whose size variation is shown in Fig. 2, all appeared above ground between March 29 and April 2. This affords some measure of root size variability where differences in time of germination and spacing are minor factors.

Summary

Carrots grown for bunching are highly variable in root size. Since an entire field is harvested at one time, there is considerable loss of yield through cullage. Data were collected to determine the effect of (a) spacing, and (b) non-uniform germination, on root size. The effect of percentage of germination and seed weight on seed requirement per acre is discussed in relation to spacing.

Examination of roots *in situ* in the field indicated that root diameter had little relation to spacing. Marking seedlings as they germinated in the field showed that time of germination was related to root size at harvest. This effect on size apparently results from competitional advantage of earlier over late seedlings. In so far as close spacing would increase this competition it would increase root size variation. Attention is directed to the extreme inherent variation in size among carrot roots even where differences in time of germination and spacing are small.

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Reduction of Storage Losses in Sugar Beets by Ventilation[1]

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HUNDREDS of thousands of tons of sugar beets are stored in open piles in the autumn, before being processed. Harvest periods are short and storage is necessary. Losses of sugar during storage are extremely costly. Because of the large volumes involved, refrigeration or cold cellars have been considered prohibitive in cost. In recent years, however, there has been great interest in the use of cold night air to reduce beet pile temperatures. Pack (7) in 1924 published data on respiration losses in beets as a function of temperature. Barr, Mervine and Rice (2) reported on sugar losses in beets in storage piles. They also determined the variation of respiration rates of beets with temperature. Fort and Stout (5) used ventilation to reduce sugar losses in a small pile and indicated further work was desirable. Barmington (1) described basic engineering considerations for commercial ventilation. M. G. Frakes (6) pioneered the development of successful commercial ventilation. Doxtator and Downie (4) have also successfully ventilated beets commercially. The technique described here was derived principally from the work of Frakes. Modifications are noted below. The purpose of the present paper is to publish quantitative results on sugar savings in an experiment conducted at Sidney, Montana in 1948. The experiment was designed to allow a direct comparison of the behavior of two identical beet piles, which differed only in that one was ventilated and the other was not.

EXPERIMENTAL PROCEDURE

Two piles were made simultaneously, one to be ventilated, the other to act as a check pile, not ventilated. Loads from a grower were sent first to one pile, then to the other, so that as far as possible the piles had identical beets. The piles were 20 feet high, 100 feet long and 110 feet wide at the base. Each pile contained approximately 2,600 tons. About 75 per cent of the beets were mechanically harvested, and the beets were relatively free of trash. The ventilated pile had three ducts made from second-hand oil drums, 22 inches inside diameter and 34 inches long. After the ends were removed the drums were welded into groups of four leaving a 2-inch air space between each drum, as a vent. This was accomplished by using strap iron to connect the drums. The groups of four were combined into ducts 95 feet in length, and held in place on the piling ground by a trench about 6 inches deep. The far end of the last drum in each duct was left intact, and 2-inch slots were cut around the periphery as vents. The first 15 feet of each duct were

[1]M. G. Frakes, Michigan Sugar Company, Myron Stout, U. S. Department of Agriculture, C. W. Doxtator and A. A. Downie, American Crystal Sugar Company were especially helpful in planning this experiment. Many Holly personnel, too numerous to list gave invaluable help. Particular thanks are due to H. P. H. Johnson, Sugar Beet Development Foundation, for help in the statistical phases of the work.

welded solid without the 2-inch air space. The ducts were spaced 25 feet apart and the beets were piled directly on top of them. Ventilation was provided by a blower on each of the three ducts. Each blower capacity was approximately 13,500 cubic feet per minute.

As the beets were being piled, captive samples of beets were made up and placed in the piles. These samples were made by matching beets in groups of threes as to size, all chosen from a given load. Twenty groups of three ("Triplets") were chosen from a load. The beets were then cleaned by brushing off the adhering dirt, and from each triplet one beet was placed in a ventilated pile sample, one in the check pile sample, and one in a laboratory sample. The laboratory sample was analyzed for sugar content and purity, and the other two were weighed and placed in their respective piles in open mesh cabbage bags. Each matching pair of samples was placed in identical positions in the piles. That is, they were at the same depth, the same distance from the north side of the pile, and the same distance from the starting end of the pile. Fifty captive samples were used in each pile, and distributed equally throughout them. When the piles were processed by the factory, the samples were weighed and analyzed for sugar and purity. Thus, gross loss was obtained by difference between total sugar (weight times per cent sugar) into the pile and the total sugar out of the pile. The same thing applied for purities.

Temperature measuring equipment consisted of 34 glass thermometers and an automatic recorder which hourly recorded temperatures from 24 resistance bulbs. Ten resistance bulbs and 17 glass thermometers were used in the check pile, and 13 resistance bulbs and 17 glass thermometers were put into the ventilated pile. The remaining resistance bulb was used to record the atmospheric temperature. Used brass tubes were placed in the piles at the desired locations to the required depths and the resistance bulbs and thermometers were suspended in them from corks which closed the upper end of the tubes. The thermometers were withdrawn from the tubes to be read, and then replaced until the next reading. Temperatures obtained were of the air inside the piles. These locations were uniformly spaced in the piles at 5-, 10- and 15-foot levels and at strictly similar positions in each pile, except for the three extra resistance bulbs in the ventilated pile which were placed 5 feet directly above each duct 15 feet in from the edge of the pile on the blower side in order that a record could be obtained of any freezing caused by ventilating with air at too low a temperature.

The arrangement in the experiment differed from previous commercial work in several ways. The blowers were controlled by individual thermostats. They automatically cut off when the night air dropped to 27 degrees F to avoid freezing beets. They came on automatically at a preset temperature which was determined by the pile temperature. Usually they were set to ventilate at 2 degrees F below the average temperature for the beets over each duct, unless local warm spots appeared. In that case the blower or blowers near the spot was set to come on at 5 or 10 degrees F below the maximum temperature. An electric clock was also used to determine the actual hours of ventilating.

Automatic louvres were installed on the intake side of the blowers. These louvres remained closed when the blowers were not in operation thereby preventing the cool air from leaking out of the pile through the ducts on warm days. This did not prevent cold air seepage through the side of the pile. However, without louvres a very strong outward current of cold air escaped through the ducts.

In order to check the sampling technic 11 additional sets of samples in triplicate (33 bags of beets, 20 beets to a bag) were taken for sugar analysis. The three samples in each set were labelled A, B and C to correspond to the laboratory, the ventilated and the check pile samples. The average sugar content for the 11 sets were respectively 15.4, 15.5 and 15.2 per cent sugar. Analysis of variance indicated that there was no significant difference between the samples. Thus an F value of 0.673 was obtained while a value as high as 3.49 was needed for significance. At the conclusion of the experiment, the data were also analyzed for significance by analysis of variance.

Sugars were analyzed by Sachs le Docte method (3) — a water extract of the beets was clarified with basic lead acetate and the sugar hot-water digestion read by polariscope. The apparent purity was determined by digesting 400 grams of beets in 380 grams of water for 30 minutes at 85 degrees C. They were then pressed and apparent purity run by hydrometer and 1/10 dilution method (3).

The purity value is needed for determination of available sugar. Thus, if one knows the purity of a beet juice, he can calculate the proportion of sugar that can be extracted as crystalline sugar. The remainder goes into molasses.

Results

Figs. 1 and 2 show the temperature data. The average temperature in the ventilated pile was consistently lower than that of the check pile (Fig. 1). The maximum pile temperature was also consistently lower

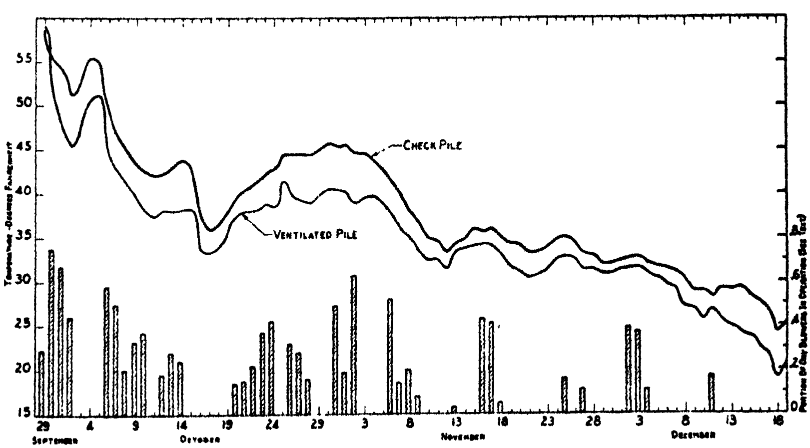

FIG. 1. Average daily temperatures taken at 4 p.m.

in the ventilated pile (Fig. 2), and here the differences were greater. The maximum temperatures were of great importance, because they would indicate a hot spot, or a possible hot spot. Such spots, once

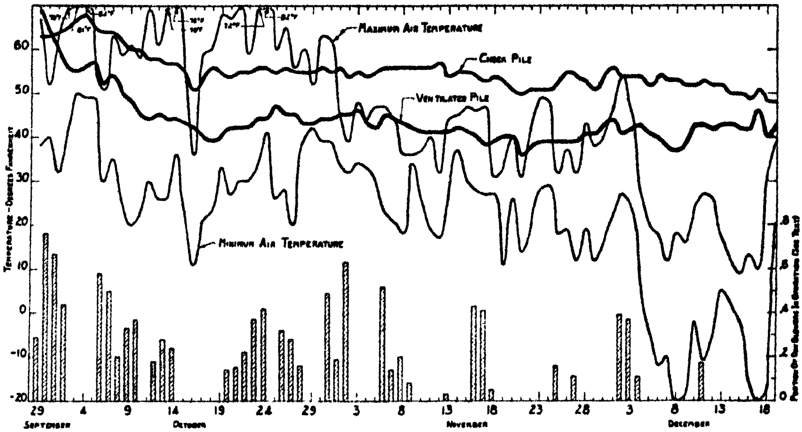

FIG. 2. Maximum daily pile temperatures with maximum and minimum air temperatures.

started, can soon result in destruction of the affected beets. Fig. 1 shows that initially the ventilated pile dropped in temperature more rapidly than the check, and it warmed up far more slowly during the October period of warm air temperatures. Temperatures were analyzed for significance on several days, and the data are summarized in Table I.

TABLE I

Date	Difference in Average Temperatures (Degrees F)	Significance
Oct 4	4.8	Beyond 1 per cent level
Oct 7	3.8	Less than 5 per cent level
Oct 14	5.6	Beyond 1 per cent level
Oct 24	4.2	Beyond 1 per cent level
Nov 1	5.4	Beyond 1 per cent level
Dec 1	1.0	Less than 5 per cent level

The smallest differences in average temperatures occur on the 2 days when significance was less than 5 per cent level.

The bars shown in Figs. 1 and 2 indicated the time blowers were in use. Thus, if the three blowers were each used 12 hours on a given day, the proportion of a total day in use would be 0.5. The greatest use of the blowers was on September 30 when 75 per cent of the maximum use was obtained. Some days the blowers were not used, because the night temperature was not sufficiently low. At the end of the season the blowers were not used, because of the extremely cold air temperatures, or because the pile was sufficiently cool. The ventilation consumed 3256 kilowatt hours for the total storage period of 85 days.

After a storage period of 85 days the two piles were processed in

TABLE II—CHANGES IN SUGAR AND IN PURITY

Sample No.	Per Cent Sugar Retention After Storage		Initial Purity	Final Purity	
	Vent Pile	Check Pile		Vent Pile	Check Pile
1	—	—	83.7	83.4	78.2
2	88.3	94.2	82.8	76.5	85.6
3	91.0	92.8	84.3	81.2	81.8
5	90.6	84.2	86.9	81.9	82.6
6	88.8	86.5	—	—	—
7	93.1	87.9	—	—	—
9	—	—	80.9	83.4	76.5
11	84.5	68.8	84.0	77.2	67.0
12	—	—	84.8	80.8	73.1
13	86.7	68.7	85.3	78.2	72.5
14	91.8	74.2	82.8	81.9	70.4
15	86.8	74.2	83.6	77.4	67.1
16	90.2	85.4	84.7	83.9	81.0
17	—	—	80.8	81.2	82.1
18	84.5	87.3	85.6	78.1	75.2
19	91.5	91.2	85.1	77.2	83.6
20	—	—	83.3	83.5	76.1
21	92.0	91.5	84.7	82.1	80.6
22	—	—	82.8	75.8	69.0
23	—	—	82.5	76.3	77.2
24	83.3	89.6	83.6	79.1	82.0
25	87.4	93.2	88.1	76.8	83.5
26	93.0	79.4	85.1	85.4	75.8
28	84.6	76.5	87.0	82.9	85.1
29	90.1	104.3	85.4	81.5	81.8
31	88.5	97.1	84.5	78.7	80.6
32	80.2	82.1	85.8	77.2	77.5
33	99.2	92.3	85.0	84.1	77.2
34	101.5	94.4	83.0	79.9	81.3
36	95.2	93.4	83.2	79.2	85.0
37	83.7	79.0	84.8	82.4	75.6
38	85.0	72.2	84.9	80.5	70.6
39	89.4	90.7	85.7	83.8	80.8
40	102.8	106.8	82.0	78.2	80.8
41	98.3	88.6	82.2	80.6	79.9
42	91.1	82.2	84.1	81.6	83.8
43	93.8	81.9	84.6	81.0	71.8
44	85.3	93.9	83.9	77.5	79.7
45	102.0	91.7	82.2	88.1	78.3
46	91.5	80.0	85.6	84.9	84.9
47	75.5	80.5	86.0	82.0	85.6
48	93.9	92.8	88.2	84.5	80.3
49	101.7	98.5	86.1	85.7	82.3
50	80.6	84.2	83.8	78.9	81.6

In analysis of variance of per cent sugar retention the F value obtained is 4.78 and an F value required for significance is 4.12 for 5 per cent level and 7.42 for 1 per cent level. In analysis of variance of purity drop the F value obtained is 6.44 and the F value required for significance is 4.08 for 5 per cent level and 7.31 for 1 per cent level.

the factory; the captive samples were weighed and analyzed. Table II summarizes the changes in sugar and purity. Samples were numbered from 1 to 50, and where a sample number is omitted in Table II the sample was lost when the beets were taken to the factory for processing. When per cent sugar retention is shown, but purity is absent, there was not sufficient pulp to determine the purity. When purity is shown, but not per cent retention of sugar, at least one beet was lost from the sample, and since both weight and per cent sugar are needed to determine per cent sugar retention, the sample was discarded as far as sugar was concerned. It will be seen that both changes in sugar and purity were statistically significant. In short, the two piles were substantially identical initially, but at the end of the storage period, the ventilated pile had 339.4 tons of sugar versus 326.4 for the check. The corresponding purities were 80.2 and 78.7. Thus, in terms of recoverable sugar using the S-J-M formula (8) there were 235 tons in the ventilated pile, and 212.7 in the check, or a difference of 22.3 tons or

446 bags of sugar. Detailed economic analyses were made which indicated an annual ventilation cost (including depreciation of equipment, labor, and so on) of 20 cents per ton ventilated, and a gross saving of approximately 70 cents per ton.

It is felt that ventilation with cold night air might be of value for other crops. For example, oranges held in bins over weekends for processing could possibly benefit from ventilation.

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Temperature Studies of Commercial Broccoli and Sweet Corn Prepackaging at the Shipping Point[1]

By R. K. SHOWALTER, *Florida Agricultural Experiment Station, Gainesville, Fla.*, and H. A. SCHOMER, *Plant Industry Station, Beltsville, Md.*

LARGE quantities of fresh vegetables are shipped from Florida to northern markets during the winter and spring months. Increasing quantities of these vegetables are being prepared and packaged in consumer units at the shipping point. To maintain freshness and prevent decay, special handling is required from the time of harvest until the vegetable reaches the consumer. During the first half of 1948 extensive studies were made on the prepackaging of broccoli and sweet corn at the farm and packing shed of a Florida grower in order to investigate the methods and problems involved in commercial prepackaging at the shipping point. The Florida Agricultural Experiment Station and the United States Department of Agriculture cooperated on this research under the Research and Marketing Act.

The importance of maintaining prepackaged produce at low temperatures has been stressed by many investigators. Scott and Mahoney (1) studied the quality changes of prepackaged sweet corn and found a decreasing sugar content with increasing temperatures and length of storage period. The United States Department of Agriculture (2) recently made a study of the prepackaging of Long Island broccoli and report a marketing period of 11 days when held at 42 degrees F, and only 4 days when held at 67 degrees.

Several physiological problems were studied, but this paper reports only the results of temperature studies made during the regular precooling, packaging and storage operations and experimental modifications of the regular methods.

MATERIALS AND METHODS

The broccoli and sweet corn were harvested and hauled directly to the packing shed. The broccoli consisted principally of secondary florets that developed on the lateral branches of the plants after the terminal flower head was harvested. A wire mesh belt conveyed the broccoli through the packing shed while it was being trimmed, washed and hydro-cooled. Many of the stems were cut lengthwise to facilitate packing in the open-top cardboard trays. Each 10-ounce tray of broccoli was then machine wrapped in cellophane and heat-sealed.

The sweet corn was mechanically husked and the ears were cut into 5- or 3-inch lengths before being washed and hydro-cooled. Both vegetables were hydro-cooled while moving on a mesh belt under a shower of mechanically refrigerated water in a 30-foot tunnel. The broccoli and part of the sweet corn were cooled for 13 minutes, but the cycle was shortened to 9 minutes in the latter part of the season to handle

[1]Grateful acknowledgment is made to L. H. Halsey of the Florida Agricultural Experiment Station and Dr. Leonard Rigg and Maurice Lieberman of the U. S. Dept. of Agriculture for assistance in various phases of the work.

the increase in volume of corn. Two types of corn packages were made with the same cardboard tray. One package contained three 5-inch ears lengthwise, and the other five 3-inch ears placed crosswise.

Ventilated cardboard master cartons containing 12 packages of broccoli or sweet corn were used for storage and shipping. As the master cartons were filled, they were stacked eight layers high in a cold storage room. The air was circulated by three blast coolers located near the ceiling. However, there was little air movement among the cartons when large numbers were placed in solid blocks. The temperature changes in the cartons were measured with a 12-unit thermocouple cable. In a typical stack eight cartons high, a pair of thermocouples (one in the center and one at the side) was placed in each of the top, middle, and bottom cartons.

Results

Series of temperature[2] readings were taken of broccoli on January 21 and February 19, starting with the field temperature and following with the temperatures after hydro-cooling and packaging. Similar series were taken of sweet corn on April 6 and 7, May 12 and June 10. These temperatures are shown in Table I with the corresponding hydro-cooler water temperatures. The temperatures were taken in the cob of the corn with fruit thermometers and inside the broccoli stems with thermocouples. The temperatures reported are averages of at least 10 readings.

TABLE I—EFFECT OF HYDRO-COOLING AND PACKAGING ON THE TEMPERATURE OF BROCCOLI AND SWEET CORN HARVESTED AT DIFFERENT DATES

Date	Hydro-cooling				Packaging			Degrees Below Field Temp. After Packaging
	Time (Min)	Water Temp.	Vegetable Temp Before	Vegetable Temp After	Decrease	Vegetable Temp Before	Vegetable Temp After	
Broccoli								
Jan 21	13	36	69	41	28	55	58	11
Feb 19.	13	--	79	48	31	57	58	21
Sweet Corn								
Apr 6	13	46	85	58	27	61	62	23
Apr 7	13	42.5	85	52	33	59	61	24
May 12	13	42 5	88	59	29	59	59	29
Jun 10								
8:15 a.m	9	40	85	50	35	54	56	29
4:30 p.m	9	41	86	53	33	—	—	—

Hydro-cooling reduced the temperature of both vegetables approximately 30 degrees F. The field temperature of the broccoli varied from 69 degrees on January 21 to 79 degrees on February 19, and the reduction to 41 degrees and 48 degrees was nearly adequate. However, during the next 7 minutes while the broccoli was being drained and packaged the temperature rose to 58 degrees. This rapid increase partly nullified the precooling effect.

The corn ranged from 50 to 59 degrees F after hydro-cooling and

[2]All temperatures are reported in degrees F.

from 56 to 62 degrees after packaging. These temperatures were too high for maintaining good quality. The water temperature in the hydro-cooler varied with the volume and temperature of the corn being cooled. Attempts were made to keep the water temperature near 32 degrees, but difficulty was encountered because of ice formation on the coils in the bottom of the hydro-cooler. Experimental lots of corn held in the hydro-cooler, with an average water temperature of 37 degrees, were reduced from 85 to 46 degrees in 20 minutes and to 41 degrees in 30 minutes.

The decrease in temperature of prepackaged broccoli in the cold storage room was compared with unpackaged broccoli in open wire baskets. The resulting temperatures, shown in Fig. 1, are the averages

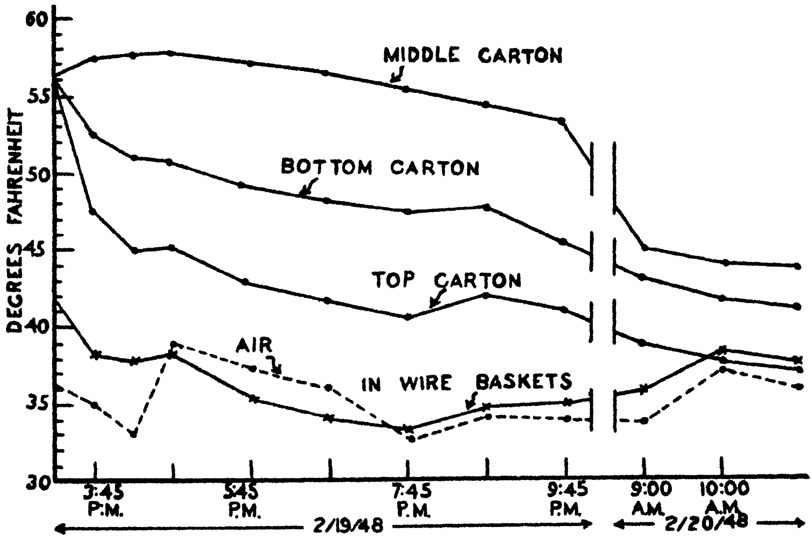

FIG. 1. Temperature changes of prepackaged broccoli during 20 hours storage at the top, middle and bottom positions in a stack of eight cartons compared with unpackaged broccoli stored in open wire baskets.

of the side and center positions in the top, middle and bottom cartons of the stack, or the side and center of the wire baskets. The wire baskets were filled with broccoli immediately after hydro-cooling and taken directly to the cold storage. Broccoli that was hydro-cooled at the same time was prepackaged and placed in storage in the regular cartons. When thermocouples were placed in the two lots the temperature of the broccoli at all positions in the stack of cartons was 56 degrees, while the unpackaged broccoli was 42 degrees. The packaged lot had increased 14 degrees before reaching the cold storage. The temperature in the middle carton continued to rise slowly during the first hour in storage and remained the warmest position with temperatures of 55 degrees after 5 hours, and 44 degrees after 19 hours. The coldest position was in the top carton which received the most air circulation. It reached the air temperature (37 degrees) after 19 hours,

as contrasted to 1 hour and 30 minutes required for the unpackaged broccoli to reach the air temperature. The temperatures at the bottom of the stack averaged about midway between the top and middle positions.

Cartons of prepackaged broccoli were held in 35, 45 and 70 degrees storage rooms to determine the changes in quality at the different temperatures. Broccoli held at 35 degrees was fresh and green after 7 days and after 13 days was only slightly discolored on the cut surfaces. At 45 degrees a small amount of soft rot and discoloration was found after the second day. After 2 days at 70 degrees the majority of the packages were unsalable because of decay. Hydro-cooled lots remained fresh longer than non-cooled lots stored at 45 and 70 degrees.

Since the sweet corn temperatures varied from 56 to 62 degrees after hydro-cooling and packaging, it was necessary to finish the cooling in the cold storage rooms. Thermocouples were placed in four experimental lots of corn to determine the cooling rates of packaged and unpackaged, and husked and unhusked corn. Table II shows the temperature of the regular prepackaged corn (A) had reached a low of 44 degrees after 18 hours in the cold room with the air temperature fluctuating from 33 to 40 degrees.

TABLE II—EFFECT OF HUSKING, HYDRO-COOLING, AND PREPACKAGING ON THE COOLING RATE OF SWEET CORN DURING STORAGE. THE TEMPERATURES (DEGREES F) WERE TAKEN IN THE COB WITH THERMOCOUPLES AND ARE AVERAGES OF THE MIDDLE AND TOP POSITIONS IN THE CARTONS OR BASKETS

Treatments	Number Hours in Storage						
	0	1	2	3	5	7	18
A—Regular hydro-cooling, prepackaging and cold storage in cartons	53	53	50	48	54	50	44
B—Hydro-cooler to cold storage in wire baskets. Prepackaged after 3½ hours	48	42	38	34	42	40	39
C—Same as treatment B except no hydro-cooling	81	45	41	37	45	42	40
D—In husk, field to cold storage in wire baskets..	83	69	60	55	52	45	38
—Air temp. in cold storage	36	39	40	34	39	33	40

Two lots of husked corn, one hydro-cooled (B) and one uncooled (C) were placed in the cold room unpackaged in wire baskets. After 3 hours the hydro-cooled lot had dropped to 34 degrees and the air cooled lot to 37 degrees. Both lots B and C were then prepackaged and the temperatures were 4 and 5 degrees lower after 18 hours than the regular pack, with the additional advantage of more rapid cooling. Lot D was placed in wire baskets in the cold room without being husked and the temperature dropped slowly to 38 degrees in 18 hours.

Prepackaged sweet corn stored for 10 to 15 days at 35 degrees was still in a marketable condition, but there was some loss of the original sweet flavor and some packages had a slight fermented odor upon opening. A similar decrease in quality was noticeable after 5 days at 45 degrees storage.

SUMMARY AND CONCLUSIONS

The 30-foot mechanically refrigerated hydro-cooler studied in these tests had sufficient cooling capacity to reduce the temperature of broccoli and sweet corn approximately 30 degrees F during a 9 or 13

minute cycle. When the field temperature of the vegetable was high, this was not sufficient cooling, since temperatures below 40 degrees were desired. With a water temperature of 36 to 46 degrees the broccoli was cooled to 41 to 48 degrees and the sweet corn to 50 to 59 degrees. The broccoli temperature increased from 10 to 15 degrees during packaging. Additional precooling was necessary after prepackaging and the cartons were placed in cold storage for that purpose. Cooling was slow and varied according to position in the room. Broccoli and husked sweet corn in open wire baskets in the 33 to 40 degrees storage room cooled more rapidly than prepackaged sweet corn and broccoli or corn in the husk, because of the insulating effect of the container and the husk.

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Effect of Irrigation on the Growth and Yield of Sweet Corn[1]

By John H. MacGillivray, *University of California, Davis, Calif.*

Crops vary in their need for supplementary amounts of water under semiarid conditions. Sweet corn in its rapid growth near maturity, its shallow root system, its failure to form ears in dry weather in humid areas, and the claim of its need for adequate water at the time of ear setting, is one of the more interesting crops from the standpoint of irrigation. This study covers these considerations, with the exception of the last item which would probably require a separate experiment for full coverage.

Some considerations relative to the general aspects of irrigation in the West have been published by MacGillivray and Doneen (4). The research data for these studies and other crops are available in mimeograph form (5). The latter study includes the results obtained with some 13 crops. Irrigation studies by Stover (7) in Oregon about 1910 gave a 2 per cent increase in yield for Stowell's Evergreen and 96 per cent increase for Early Minnesota, the latter probably the more shallow-rooted variety. Voorhees (8), working in New Jersey about 1899, found that irrigation increased sweet corn yields 52 per cent and other vegetables from 9 to 73 per cent. Cordner (1) in Oklahoma, grew Country Gentleman in 1940 and Golden Colonel in 1941 in an irrigation experiment. Both are tall varieties of sweet corn. Each year was fairly favorable for production without irrigation. In 1940 irrigation increased yield 25 per cent and in 1941, 55 per cent. Corn was irrigated rather frequently, but the amount of water applied was not measured. Haber (2) reports a study made in Iowa comparing inbred lines of sweet corn that were susceptible and resistant to drought. He was unable to find any morphological or physiological test capable of separating these two types of plants.

Studies of field corn have also been made. The two most applicable to this work were by Miller and Duley (6) and Haynes (3); the experiments in both studies were carried on in large metal containers. The growth period (6) of the corn was divided into three periods with various treatments given to the plants such as maintaining optimum (28 per cent) and minimum (13 per cent) soil moisture. Fourteen different treatments were used. The amount of moisture available in the first 30 days was of least importance in affecting growth, and that available in the last 30 days was of most importance. Minimum soil moisture gave a higher nitrogen and mineral content than did optimum moisture. Haynes (3) grew corn plants in jars of 4-liter capacity which contained soils at different moisture levels. The author states that the quantity of vegetative growth was markedly affected by the amounts

[1]These experiments were conducted under a joint project of the Irrigation and Truck Crops Division. The author was responsible for the plant data and Dr. L. D. Doneen of the Irrigation Division for the soil data. Amount of water applied, number of irrigations, and plant height measurements were supplied through the kindness of Dr. L. D. Doneen.

of available soil moisture. The range was from near saturation to near the permanent wilting percentage.

Methods

These studies were started in 1939 at Davis, and continued during 1940 and 1941. In the first year the Golden Cross Bantam variety was used; the preliminary results were similar to those obtained in subsequent years. Since the effect on yield was great, it seemed desirable to compare a small variety, Golden Bantam, and a large variety, Oregon Evergreen. Each treatment was applied to soil initially filled with available water to a depth of 6 feet. Treatment A plots received no irrigation water; those of treatment B received the greatest amount of water while those of treatments C and D received successively smaller amounts of water. Each plot was 1/115 of an acre; rows were 3 feet apart with single plants 12 to 15 inches apart in the rows, and the treatments were replicated four times. All crops were planted in the spring, and none was suckered. Records were obtained of the following: relative rate of growth, number of suckers per plant, plants with tassels, and plants with silks. The yield was determined in terms of marketable and unmarketable ears, and the marketable were of approximately U. S. No. 1 grade. After harvest the plants were cut and allowed to field-dry during July and August for dry-weight determinations of the stalks for the entire plot.

Discussion and Results

Wilting of Plants:—Most vegetable plants grown in the field do not exhibit wilting under conditions of low soil moisture. As the moisture supply declines, a reduction in growth takes place first, and finally a cessation of growth. Usually a plant is able to absorb sufficient moisture from soil below the major root regions to remain turgid. Sweet corn plants growing under such conditions, however, exhibited several degrees of wilting. The plants on the dry plots showed the greatest rolling of leaves, but wilting was also noticeable in the plants on the wet plots a day or so after irrigating. This wilting occurred at about 2 p m on hot days. Oregon Evergreen corn rooted somewhat deeper and showed less rolling of leaves than Golden Bantam (Fig. 1). The indications of insufficient water on the B treatment were unusual but perhaps could be explained by the rapid growth of corn near tasseling time. Rapidly growing corn plants may transpire so fast that the roots are unable to obtain a sufficient volume of water to keep the leaves turgid. A somewhat similar condition has been noted on Irish potatoes —another crop with a shallow and limited root system.

Size of Plant:—Tables I and II indicate that the relative weight and size of sweet corn plants are greatly affected by the amount of irrigation water. In all four experiments, the weight of the plant was proportional to the amount of irrigation water added (Figs. 2 and 3). The same effects are noticeable in the successive height measurements shown in Fig. 4. As shown in both graphs, irrigation treatment made little difference in the height of young sweet corn, but at maturity the

TABLE I—EFFECT OF IRRIGATION ON THE GROWTH OF GOLDEN BANTAM SWEET CORN (1940 AND 1941)*

Relative Amount of Water Applied	Inches of Water	No. of Irriga-tions	6 Doz Crates Market-able Ears Per Acre	Yield Per Plant: Marketable Ears No.	Yield Per Plant: Marketable Ears Lbs.	Yield Per Plant: Unmarket-able Ears No.	Yield Per Plant: Unmarket-able Ears Lbs.	Pounds Per Ear Market-able: Unhusked	Pounds Per Ear Market-able: Husked	Dry Weight Per Plant (Lbs)
1940										
None A	0.0	0	10.6	0.07	0.03	0.53	0.09	0.30	0.17	0.38
Heavy B	19.1	7	178.5	1.18	0.38	1.06	0.21	0.32	0.22	1.06
Medium C	9.3	3	140.7	0.93	0.30	1.72	0.31	0.31	0.22	0.93
Light D	8.7	3	87.7	0.58	0.18	1.42	0.26	0.31	0.22	0.74
L.S.D.† odds 19:1	—	—	56.0†	0.37	0.12	0.32	0.12	N.S.‡	N.S.‡	0.16
1941										
None A	0.0	0	84.7	0.56	0.21	0.85	0.20	0.38	0.23	0.33
Heavy B	30.9	6	243.5	1.61	0.70	1.88	0.47	0.43	0.26	0.81
Medium C	18.0	3	180.0	1.19	0.52	1.56	0.38	0.43	0.26	0.62
Light D	12.2	2	145.2	0.96	0.42	1.49	0.36	0.44	0.24	0.53
L.S.D.† odds 19:1	—	—	51.4	0.34	0.33	0.10	0.05	N.S.	0.05	0.09

*Date planted: Apr 17, 1940; Apr 24, 1941; harvested: Jul 13 to 27, 1940; Jul 19 to 31, 1941.
†L.S.D.: Least significant difference = odds 19:1.
‡N.S.: not significant.

TABLE II—EFFECT OF IRRIGATION ON THE GROWTH OF OREGON EVERGREEN SWEET CORN (1940 AND 1941)*

Relative Amount of Water Applied	Inches of Water	No. of Irriga-tions	6 Doz Crates Market-able Ears Per Acre	Yield Per Plant: Marketable Ears No.	Yield Per Plant: Marketable Ears Lbs.	Yield Per Plant: Unmarket-able Ears No.	Yield Per Plant: Unmarket-able Ears Lbs.	Pounds Per Ear Market-able: Unhusked	Pounds Per Ear Market-able: Husked	Dry Weight Per Plant (Lbs)
1940										
None A	0.0	0	12.1	0.08	0.03	0.67	0.17	0.40	0.26	0.62
Heavy B	22.2	8	166.4	1.10	0.65	0.67	0.22	0.58	0.37	1.97
Medium C	10.3	3	167.9	1.11	0.57	0.66	0.21	0.49	0.34	1.35
Light D	9.3	2	119.5	0.79	0.40	0.83	0.28	0.50	0.33	1.22
L.S.D. odds: 19:1	—	—	30.2†	0.20	0.10	N.S.‡	N.S.‡	N.S.‡	N.S.‡	0.23
1941										
None A	0.0	0	99.3	0.65	0.43	0.82	0.37	0.67	0.42	0.66
Heavy B	37.9	7	201.2	1.33	1.03	0.74	0.33	0.77	0.58	1.23
Medium C	16.0	3	178.5	1.18	0.87	0.70	0.32	0.74	0.48	1.03
Light D	11.9	2	145.2	0.96	0.72	0.94	0.39	0.75	0.49	0.96
L.S.D. odds: 19:1	—	—	21.1	0.14	0.19	N.S.‡	N.S.‡	N.S.‡	0.10	0.20

*Date planted: Apr 17, 1940; Apr 2, 1941; harvested: Aug 20 to Sep 2, 1940; Aug 4 to 11, 1941.
†L.S.D.: least significant difference = odds 19:1.
‡N.S.: not significant.

height of the corn plant was roughly proportional to the amount of water applied. The effect of insufficient water on growth can be noticed within 30 to 40 days after planting.

A count was made at successive dates (1940) of the number of suckers per plant. When the nonirrigated plants (A) and amply ir-

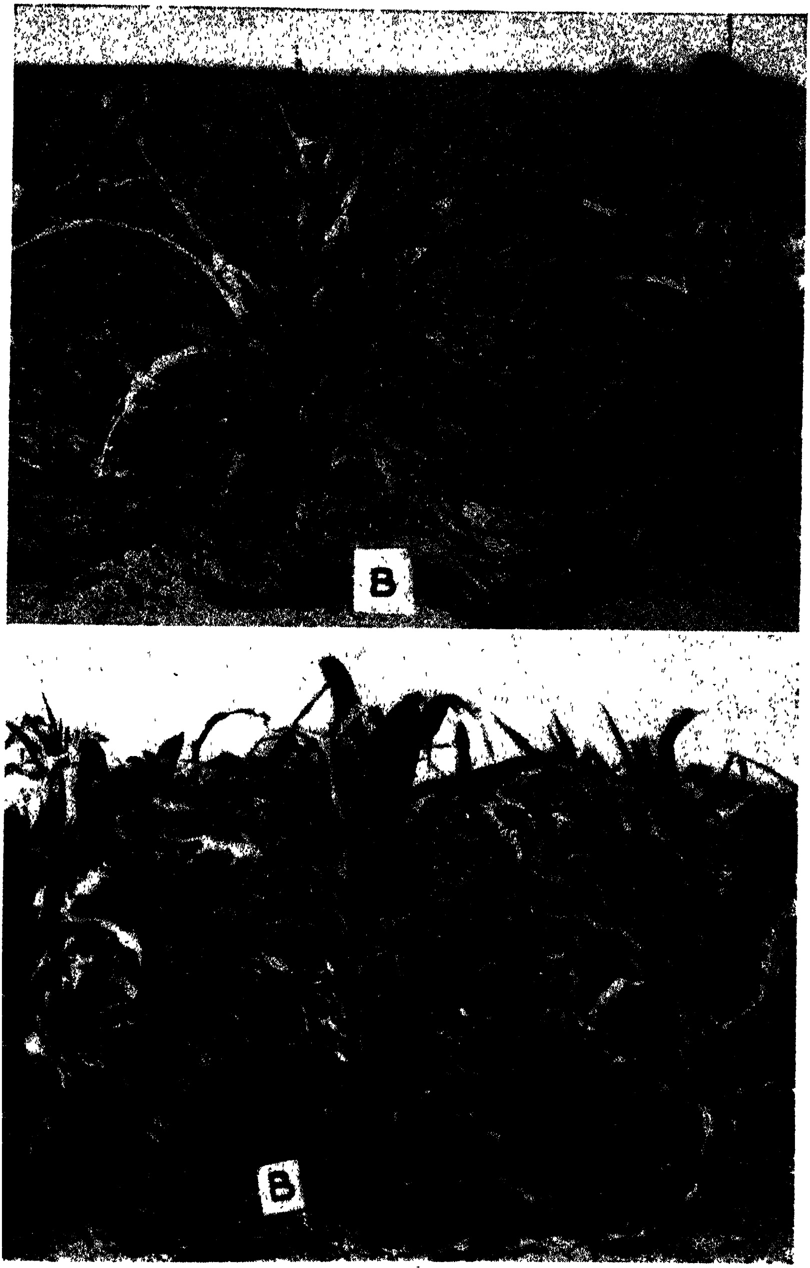
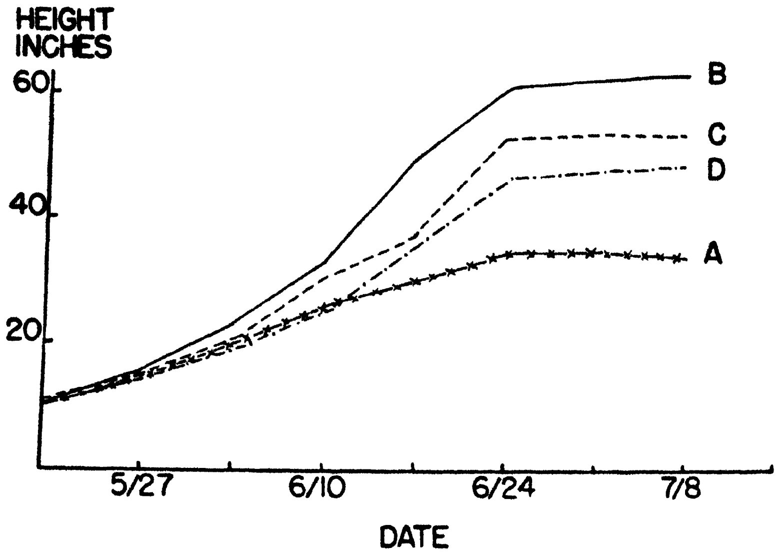


FIG. 1. Appearance of Golden Bantam (upper), and Oregon Evergreen (lower) plants on June 10. B is the wet treatment. Golden Bantam shows rolling of the leaves indicating a shallower root system.

FIG. 2. The relative growth of non-irrigated (A) and wet treatment (B) sweet corn of the Golden Bantam variety. Note the variation in the size of plants on the non-irrigated plot.

rigated plants (B) were compared, there were always more suckers on the irrigated plants than on the nonirrigated. These averages for the 1940 experiments were 2.7 suckers per plant on the dry treatment, and 3.5 suckers on the wet treatment for Golden Bantam; and 1.0 suckers versus 2.0 suckers for Oregon Evergreen. A count was made of the number of tassels per plant both in 1940 and 1941. In 1940 Golden Bantam averaged 2.6 tassels per plant on the A treatment compared with 3.9 tassels on the wet treatment (B); similarly, Oregon Evergreen averaged 1.5 tassels per plant versus 2.1. The results ob-

FIG. 3. The relative growth of non-irrigated (A) and wet treatment (B) sweet corn of the Oregon Evergreen variety.



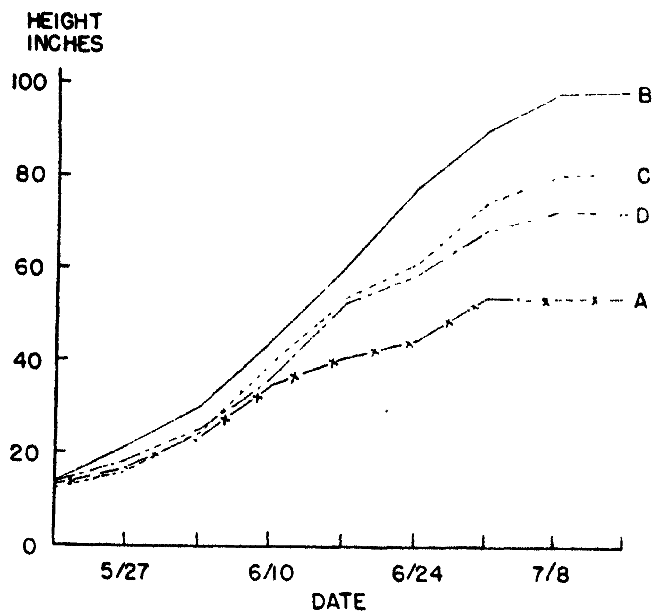


FIG. 4. Growth curves of Golden Bantam (upper) and Oregon Evergreen corn (lower). Unirrigated plants (A) were the first to show retarded growth.

tained in 1941 indicated the same tendency. In the 15 comparisons made, only one dry treatment had more tassels per plant than the wet treatment. Similar results were obtained in the number of ears with silks. In all 15 comparisons there were always more ears with silks on plants of the wet treatment. The relative values per plant for A and B treatments and Golden Bantam were 0.9 to 2.4 in 1940, and 1.8 to 4.2 in 1941. Similar data for Oregon Evergreen were 1.4 to 2.2 in 1940, and 1.6 to 2.2 in 1941.

Weight of Corn:—The average increase in yield from irrigation in these five experiments was 2,281 per cent. This was the greatest increase obtained for any crop in studies at Davis; and may be compared with 35 per cent obtained from averaging five deep-rooted crops. The data in Tables I and II give the relative amount of irrigation water added, the number and pounds of marketable ears per plant. Many of these differences are significant at the 5 per cent level. Both varieties gave greater yields in 1941 than in the previous year. Few ears were produced on the nonirrigated plots; these were usually poorly filled with grains, and marketable ears were rare.

Size of Ear:—The data on ear size recorded in Tables I and II are limited to marketable ears, and do not exhibit as great differences in size of ears as might be expected. The average weight of all ears per treatment is not greatly different but the nonirrigated treatment always produces the smallest ears. If the weight of edible corn had been compared, rather than the weight of corn, cob, and husk, it is believed the differences between treatments would have been greater.

Composition of Corn:—The data in Table III indicate that irrigation treatments have affected the composition of the corn kernels. Insufficient soil moisture increased the percentage of dry matter as well as its various constituents, such as sugars and nitrogen. These results are similar to those obtained by Miller and Duley (6) for field corn.

TABLE III—COMPOSITION OF KERNELS FROM IRRIGATED SWEET CORN

Treatment: Amount of Irrigation	Per Cent Dry Matter		Golden Bantam—Per Cent			
	Oregon Evergreen	Golden Bantam	Sucrose	Total Sugars	Soluble Nitrogen	Total Nitrogen
A - none	31.8	34 4	3 2	3 6	0.34	0.79
B - heavy	28.9	31 4	2.9	3.3	0.31	0.72
C—light	31.5	32.5	3.0	3.3	0.33	0.76

SUMMARY

The growth of sweet corn is greatly reduced by insufficient soil moisture as measured by yield of marketable ears, size of plant, and dry matter produced. The size of marketable ears is only slightly smaller but many ears were of no market value when the moisture supply was limited. The leaves of a corn plant roll with insufficient soil moisture, and growth may be so rapid that this condition exists for a short period each day on plants receiving ample applications of irrigation water.

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A Device for Handling Small Experimental Seed Lots on a Gravity Separator

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One of the problems of conducting experiments in the production of vegetable seed is handling small lots of seed by methods comparable to those used by commercial producers. For example, in some of the experiments now being conducted at the Utah Agricultural Experiment Station with carrots, lettuce, and onions, many different cultural treatments are being tried. In these the yield of re-cleaned seed is an important criterion, and thus it is desirable that the seed not only be threshed by commercial methods, but be subjected as nearly as possible to the same processes through which it would go in a commercial seed house. The problem of threshing these small lots has been solved by the development of a small type threshing machine capable of handling over a hundred different seed crops (1). Except for one of the last operations used by modern seedsmen, cleaning small lots of seed has in some ways been easier, as small fanning mills and screen separators have been available for many years. However, so far as is known, there is not available any small equipment comparable to the modern gravity separator used by most seedsmen today. It is possible that one may be able to clean seed by using hand sieves and similar small type equipment, but the final yield is not likely to be the same as though the seed were run through larger power-operated machines. This problem has been solved by the authors through the development of an accessory frame which when attached to the deck of a gravity separator makes it possible to clean successfully amounts of seed less than ¼ pound as compared to the several pounds of uncleaned seed normally left on the deck of even the smallest machines. In many gravity separators this irreducible remainder may be 10 pounds or more.

During the operation of a gravity separator, a uniform layer of moving seed must extend over the entire surface of the deck. The shaking of the deck, its tilt, and the stream of air that comes up through it, separates the seed on the basis of weight, the heavier seed moving toward the upper edge and the lighter material moving toward the lower area of the deck. However, to obtain satisfactory separation there must be both a uniform layer of seed and a sufficient time lapse for the separations to occur before the seed falls from the deck into the various chutes or bags placed along one side. It has been generally thought that the separations would not take place satisfactorily on any deck smaller than the smallest commercial machines now made. However, it is a fact that excellent separations have been made by using the Deck Reducer frame developed in the Seed Cleaning Laboratory at the Utah Station. This frame, as the name suggests, actually reduces the area over which the seed travels and within which the various separations occur.

As Fig. 1 shows, the reducer frame approximately duplicates on a

smaller scale the proportions of the original deck. It is estimated that the cost of materials should not exceed $2 in any section of the country, and a competent carpenter or handy man could make the entire frame within a few hours. It can be attached to a commercial machine within a few minutes with a few turns of several wing nuts. The method of attachment, of course, might necessarily vary somewhat, depending upon the make of machine.

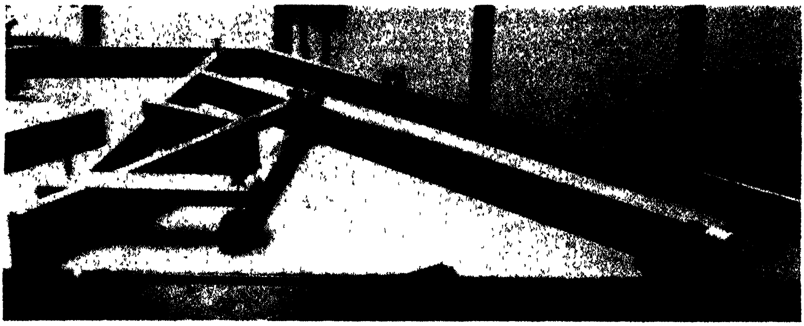

FIG. 1. The deck reducer in place. The ledge marked R is at the rear of the full commercial sized deck. The ledge in front of it is at the rear of the reduced deck, and the seed separation takes place mostly in the triangle in center foreground.

The data in Table I indicate both the smallness of the samples which can be cleaned and the irreducible amounts of uncleaned seed left on the deck.

TABLE I—A COMPARISON OF QUANTITIES OF SEED REMAINING ON A DECK OF A SMALL GRAVITY SEPARATOR WHEN USED WITH AND WITHOUT DECK REDUCER

Crop	Deck Size Used	Number of Replications	Weight of Seed, Including Foreign Material (Lbs)		Ratio Between Remainders
			Initial Uncleaned	Average Irreducible Remainder	
Carrot	Full size	6	14.000	3.58 ±0.27	
	Reduced	6	0.220	0.06 ±0.013*	60:1
Onion	Full size	1	13.25	1.75	
	Reduced	6	0.22	0.05 ±0.011*	35:1
Lettuce	Full size	3	5.42**	2.41	
	Reduced	6	0.22	0.09 ±0.020	27:1

*The odds are 19:1 that remainder would be within these limits.
**Average of three lots ranging from 4.25 to 7.75 pounds.

Since the deck reducer was designed and first tested many weeks after most of the seed of onions and lettuce had been cleaned, the limited quantity of seed available for the tests contained more chaff and other light weight material than is normally found in seed ready to be run over a gravity machine. Thus, the irreducible amounts of 1.75 and 2.41

pounds of onions and lettuce, respectively indicated in Table I as being left on the full size deck, are probably much below the normal weight which would usually remain. With the carrot there was plenty of seed available to test, and in addition it was typical of the material ready for cleaning on a gravity separator.

In spite of these drawbacks to the data for onions and lettuce, it is obvious that the deck reducer still made it possible both to clean and have left on the deck extremely small quantities of seed. The ratios between remainders left on the standard and reduced decks were 60:1, 35:1, and 27:1 for carrot, onion, and lettuce seed, respectively. For those who are not familiar with the gravity machine it should be pointed out that the irreducible remainder would be approximately the same, irrespective of the initial uncleaned weight, provided all the other conditions (the actual seed lot, size, type, and adjustment of machine) were the same. Normally a seedsman using the full deck would commence his operations with much more seed than 14 pounds of carrot or 4 pounds of lettuce. The weight would more likely be up in the hundreds of pounds. Likewise, when using the deck reducer, the initial weight of seed could be more than ¼ pound. Actually, any weight from that amount up to 4, 5, or 6 pounds could be handled conveniently, but the irreducible remainders would approximate those obtained in the tests. Since the deck reducer can be installed within a few minutes, it is possible, of course, when using the full deck to sweep the remaining seed from the deck at the end of a run, install the reducer, pour the seed into it, and within a few minutes have a much smaller uncleaned remnant. In other words, for all practical purposes by the simple installation of the deck reducer at the end of the full deck run, any of the six 14-pound lots of carrot seed listed in Table I could easily have been cleaned to the point where much less remained on the reduced deck. In seed production studies where it is desirable both to clean the seed by commercial methods and to determine accurately the weight of cleaned seed, the deck reducer can be of inestimable value. For the worker handling stock seed, whether seedsman or researcher, the device offers an opportunity to clean small quantities of seed to a point where they will handle easily in any planter and look acceptable to the contract grower.

Anyone who would like to have a large scale diagram showing the construction of the reducer in detail, together with suggestions for installation on various machines, can obtain a copy free of charge by writing the authors directly. Instructions for the operation of the reducer will also accompany the diagram.

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Factors Affecting the Objective and Organoleptic Evaluation of Quality in Sweet Corn[1]

By AMIHUD KRAMER and R. B. GUYER, *University of Maryland, College Park, Md.*, and L. E. IDE, *U. S. Department of Agriculture*

THE quality of sweet corn that is consumed in the fresh, frozen or canned state is determined primarily by the degree of succulence, the quantity and toughness of the pericarp, and flavor.

The consumer who purchases corn in the raw state must, of necessity, buy entirely on the basis of external appearance so that aside from such factors as size of ear and freedom from insect damage his selection is made primarily on the basis of the appearance of freshness. It may be expected, therefore, that in the case of first purchases especially, the consumer will select ears that have well-filled but not dented kernels. This dented appearance may be due to a delay in the harvesting of the corn, or a prolonged holding period of the corn after harvesting.

Repeat purchases of fresh corn and corn for canning and freezing involve the other factors of pericarp and flavor as well as succulence. Pericarp content is a varietal characteristic which is modified by the stage of maturity. Haber (6) has shown that the pericarp content of corn in the dry state may vary from 4.76 per cent for Golden Cross Bantam to 8.34 per cent for Stowell Evergreen. Kramer (8) found that very young Country Gentleman corn contains 1.88 per cent pericarp while mature Country Gentleman contains 4.13 per cent pericarp. Similarly, very young Golden Cross Bantam corn contained 1.38 per cent pericarp while more mature Golden Cross Bantam corn contained 2.28 per cent pericarp. Bailey and Bailey (3) indicate that the pericarp becomes thinner and harder as the corn matures.

The problem of flavor is a difficult one, both from the standpoint of definition as well as objective measurement. Chemical composition is important. Sugar content is by no means all that needs to be considered. As early as 1923, Appleman (1) emphasized sugar-starch ratio; Culpepper and Magoon (5) stated that high sugar content does not always mean high flavor, and suggested that the ratio of water soluble to total polysaccharides may affect quality as well as the compactness with which the polysaccharides are laid down and the cellular structure of the endosperm itself.

Since succulence, pericarp content and flavor were considered to be closely correlated and primarily influenced by the stage of maturity (7), many attempts have been made to measure by a single test the over-all quality of sweet corn for canning. The various moisture tests (10, 11), as well as the succulometer test (9), may be considered to be primarily measures of succulence, being measures of other factors only to the extent that they are correlated with succulence. The puncture

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test (4) and the pericarp test (8) may be considered tests of pericarp toughness and content, respectively. Measurements of refractive index (12) may be considered to be tests of flavor since they measure the soluble solids content which consists primarily of sugars.

Since all of these factors of succulence, pericarp and flavor are affected not only by the stage of maturity of the sweet corn, but also by varietal differences and conditions of storage of the raw product, these studies were designed to cover these variables as they would be found under commercial conditions in the field, the factory yard, or the market and retail outlets.

Materials and Methods

The following varieties were planted in the summer of 1948 at the Plant Research Farm of the University of Maryland: Seneca Chief, a high quality golden sweet corn used primarily for fresh market purposes; Golden Cross Bantam and Ioana, two commonly-used varieties for the fresh market as well as for canning; Country Gentleman, representing the shoe-peg type of white corn; and Narrowgrain Evergreen, representing the large kernel type of white corn. The yellow varieties were harvested three times, representing very young, young, and nearly mature stages of maturity. The white varieties were harvested twice, representing very young and nearly mature stages of maturity. As each lot was harvested, it was brought into the laboratory where a sample was removed for immediate analysis. The remaining material was divided into five lots. Four of these lots were placed in chambers where the temperature was held at 35, 50, 70, and 88 F, degrees, respectively. The fifth lot was held in lug boxes and covered with about 4 inches of crushed ice. The ice was added as needed during the entire storage period. A sample was removed from each storage chamber 1 day, 3 days, 5 days and 7 days after harvest, for analyses.

Each sample was first husked. Nubbins and badly damaged ears, were discarded and not included in the analyses. A 20-ear lot was removed for the raw grade determination, which was made by a United States Department of Agriculture grader who modified the official method, as follows: each ear was placed in one of five categories; categories 1 to 3 covering the range equivalent to U.S. No. 1, and categories 4 and 5 which were too mature to meet the requirements for U.S. No. 1. The per cent of ears falling into each category was calculated. The percentage of ears which fell into each grade was multiplied by the number of the grade. These products were then totalled to give one single value for the raw grade.

The kernels were cut from the remaining ears, care being taken not to add any external moisture; a succulometer reading was obtained in duplicate, and a sample removed for moisture determination by the official vacuum oven method. Pericarp determinations were made, as follows:

1. Blend 100 grams of kernels with about 200 ml water in a Waring blendor for 5 minutes.

2. Weigh 50 grams of the above blend and wash through a 30-mesh screen, using liberal quantities of water, until all of the comminuted material has gone through the screen and only the shredded pericarp remains on the screen.
3. Dry the screen and pericarp at 100 degrees C for 2 hours and weigh.
4. Flame the screen until the organic material has been destroyed, cool, and weigh.
5. The weight of the screen plus dry sample, minus the weight of the flamed screen, multiplied by four, equals per cent pericarp.

The remaining kernels were blanched in water for 2½ minutes at 190 degrees F, filled into cellophane-lined containers, frozen at −20 degrees F, and stored until tested at 0 degrees F. When used for organoleptic determinations, they were cooked for 12 minutes in boiling water.

The organoleptic determinations were made on this frozen material because it was considered practically impossible to compare closely the quality of the samples over a long period of time. These organoleptic determinations on the frozen product, on the other hand, provided the opportunity of grading all of the samples at the same time. Scores for succulence, skin character (pericarp), and flavor were recorded separately by a panel of six judges who scored each factor on the basis of 1 to 10. In the case of succulence, it was recognized that it is possible to obtain material that is entirely too watery and thus lacking in body. Hence, the value of 8 was agreed upon as being optimum for succulence, 9 being too young, and 10 entirely too watery. For the factor of pericarp and flavor, 10 indicated the best quality, and 1 the poorest.

Discussion of Results

The data in Table I show the extent of agreement between the various objective and organoleptic methods for measuring quality. The extremely high correlation of .92 between moisture content and

TABLE I—Correlation Coefficients Between Objective and Organoleptic Evaluations of Quality Factors (Samples of All Varieties Included)*

Evaluation	Objective			Organoleptic			
	Moisture (Per Cent)	Succulometer (Cc)	Pericarp (Per Cent)	Raw Grade**	Succulence†	Skin Character†	Flavor†
Moisture (per cent)	----	0.92	0.66	0.93	0.86	0.83	0.66
Succulometer (cc)	0.92	----	0.66	0.88	0.87	0.79	0.71
Pericarp (per cent)	0.66	0.66	----	0.65	0.70	0.76	0.69
Raw Grade**	0.93	0.88	0.65	----	0.88	0.87	0.78
Succulence†	0.86	0.87	0.70	0.88	----	0.96	0.83
Skin Character†	0.83	0.79	0.76	0.87	0.96	----	0.73
Flavor†	0.66	0.71	0.69	0.78	0.83	0.73	----

*260 samples for which all the analyses were available were used. All correlation coefficients higher than 0.18 are significant at the 1 per cent level.

**Determined from a calculation of grades as provided by United States Department of Agriculture grader for raw corn.

†Provided by a panel of judges who scored each sample for the three quality factors.

succulometer values indicates that these two methods measure very much the same thing and may, therefore, be used interchangeably. The extremely high correlation between moisture content and the grade of the raw material is very significant in several respects. First, it shows that either moisture determination or succulometer determination is very closely correlated with the official grades for fresh corn. Secondly, this may indicate that the official graders of fresh corn consider succulence as the outstanding factor of quality. It may also be assumed from this high correlation that, in general, the consumer of fresh corn makes his preference on the basis of succulence rather than tenderness or flavor. The moisture determination was closely correlated with organoleptic determinations for succulence and skin character on the frozen samples, but not with flavor. Therefore, it may be concluded that moisture determination is not a good measure of flavor under certain conditions. Since the correlations for succulence and skin character were definitely lower than the correlation for raw grade, it may also be assumed that under certain conditions moisture determination may not be entirely satisfactory in measuring succulence and skin character. The correlation between moisture content and per cent pericarp was also significantly lower, indicating that these two tests do not measure the same thing under certain conditions.

The correlations between succulometer values and the other tests are very similar to the correlation between moisture and other tests, thus again indicating that the succulometer values may be used interchangeably with moisture values. The pericarp test was not as accurate in predicting the raw grade or the organoleptic rating of succulence as were succulometer and moisture, but was about equal to the other tests for measuring skin character and flavor.

In comparing the organoleptic grades with each other, the correlation of .96 between succulence and skin character is indicative of the probability that the judges were influenced to an excessive degree by their rating for succulence when deciding on the rating for skin character.

In attempting to account for some of the lack of agreement among these various tests, the data were analyzed statistically by the analysis of variance. This method makes it possible to show the effect of the various factors on the test values, and also makes it possible to study the simultaneous effects of these factors in combination. The data for the golden sweet corn varieties are presented in Table II. It is obvious that the stage of maturity as indicated by date of harvest exerts a tremendous influence on all of the tests, but does not appear to be quite as important for flavor as for the other tests. Thus, where there are large differences between the first and second harvest as measured by other tests, in respect to flavor, the corn from the first harvest was only a little better than that of the second harvest.

The factor of duration of storage had a significant effect on all of the tests, but seemed to be relatively more important for pericarp and the organoleptic measures of skin character and flavor. Thus, the increase in pericarp content from 1.80 per cent to 2.72 per cent was almost equal to that resulting from delay in harvest, whereas the change in moisture

content was only 3.5 per cent after 7 days' storage, compared to 13.8 per cent loss resulting from delayed harvest.

The factor of temperature of storage was generally somewhat less important than the factor of duration of storage, especially for all of the organoleptic measures.

The factor of variety was of some importance. However, no conclusions as to relative merit may be drawn, since the different varieties were not necessarily harvested at exactly the same stage of maturity. Since the organoleptic evaluations appeared to be affected about the same way as the objective measures, it appeared that the varietal factor as among the yellow varieties was not very important in reducing the degree of correlation among the tests.

The analysis of variance for the white corn varieties is given in Table III. Here again, the stage of maturity as indicated by date of harvest is the most important factor and, again, is less important in the case of flavor. Also, as with the golden corn, temperature of storage is not quite as important as duration of storage. Regarding the

TABLE II—SWEET YELLOW CORN—EFFECT OF VARIETIES, DATE OF HARVEST, DURATION AND TEMPERATURE OF STORAGE, ON OBJECTIVE AND ORGANOLEPTIC MEASUREMENTS OF QUALITY FACTORS (COLLEGE PARK, 1948)

	Objective Measures			Organoleptic Measures			
	Moisture (Per Cent)	Succulometer (Cc)	Pericarp (Per Cent)	Raw Grade	Succulence	Skin Character	Flavor
Main Order Effects							
1. *Date of Harvest*							
1st harvest	75.6	22 1	1 77	7 6	7.5	7 6	5 7
2nd harvest	68 7	18.6	2.28	5 6	6 1	6.3	5 0
3rd harvest	61.8	11.7	2.74	3 6	3.3	3.7	3 2
L S.D.	0 56	0 48	0 082	0.19	0 22	0.19	0 26
F value	1339.9	1000.2	281.5	877 5	811.6	951 1	192 9
2. *Duration of Storage (Days)*							
0	70.7	19.7	1.80	6.8	7.0	7 2	6.1
1	69.3	18.2	2.13	6 4	6 0	6.6	4.9
3	68.2	16.5	2.22	5.5	5.4	5 8	4.7
5	67.3	16.4	2.48	4.9	4.9	5.0	3.9
7	67.2	16.3	2.72	4 6	4.6	4.7	3.6
L S.D.	0.72	0.61	0.106	0.25	0.27	0.22	0.34
F value	33.2	47 3	87.7	111.7	97.4	145.0	145.2
3. *Temperature of Storage (Degrees F)*							
35	69.0	18.4	1.97	6.0	6.3	6 5	5.6
50	68.6	17.3	2.15	5.6	5 8	6.2	5.1
70	68.0	16.4	2.44	5.3	5.2	5.5	4.1
88	66.8	16.0	2.70	4.9	5.0	5.2	4.0
Iced	70.2	19.0	2 08	6.2	5.8	5.9	4.4
L.S.D	0.72	0.61	0.106	0.25	0.27	0.22	0.34
F value	24.8	35.3	63.2	38.4	30.7	39.9	39.9
4. *Varieties*							
Seneca Chief	71.2	19.5	2.08	6.2	6.3	6.4	4.9
Golden Cross							
Bantam	66.7	16.5	2.27	5.3	5.1	5.6	4.6
Ioana	67.7	16.2	2.45	5.4	5.4	5.5	4.4
L.S.D.	0.56	0.48	0.082	0.19	0.22	0.19	0.26
F value	143.6	115.0	39.5	54.3	62.2	61.9	5.65

TABLE II—(*Continued*)

Harvest	Days	Objective Measures: Moisture (Per Cent)	Succulometer (Cc)	Pericarp (Per Cent)	Organoleptic Measures: Raw Grade	Succulence	Skin Character	Flavor
				Interactions				
1 × 2—Dates of Harvest by Duration of Storage								
1st	0	78.2	24.5	1.33	9.0	8.6	8.8	7.3
	1	76.4	22.6	1.61	8.8	7.8	8.5	6.3
	3	75.7	21.7	1.74	7.8	7.3	7.4	5.5
	5	73.4	21.3	2.03	6.7	6.9	6.9	4.7
	7	74.5	20.3	2.15	5.9	6.6	6.6	4.7
2nd	0	71.1	20.8	1.89	7.0	7.2	7.6	6.9
	1	68.5	19.7	2.26	6.2	6.9	7.0	5.1
	3	68.5	17.7	2.07	5.3	6.1	6.2	5.0
	5	68.2	17.2	2.39	4.7	5.4	5.6	4.3
	7	67.3	17.4	2.82	4.6	4.0	4.9	3.5
3rd	0	62.7	13.9	2.16	4.3	5.3	5.1	4.0
	1	62.9	12.2	2.51	4.0	3.3	4.2	3.3
	3	60.4	10.2	2.85	3.3	2.9	3.7	3.6
	5	60.2	10.8	3.03	3.3	2.4	2.6	2.8
	7	60.0	11.2	3.18	3.3	2.4	2.7	2.4
L.S.D.		1.24	1.06	0.183	0.42	0.48	0.41	0.59
F value		2.85	1.61-	3.72	10.8	4.34	1.83-	4.25
Harvest	Degrees F							
1st	35	75.6	23.1	1.49	8.1	7.9	8.2	6.9
	50	75.5	21.7	1.70	7.7	7.5	8.0	6.0
	70	75.4	20.9	1.90	7.2	7.2	7.3	5.2
	88	73.7	20.1	2.21	6.6	6.7	6.8	5.0
	Iced	77.9	24.4	1.56	8.4	7.9	7.9	5.6
2nd	35	69.6	19.7	1.98	6.1	6.9	7.0	6.0
	50	68.9	18.4	2.19	5.5	6.4	6.5	5.7
	70	67.7	16.9	2.58	5.2	5.4	5.7	4.2
	88	67.3	17.3	2.56	4.8	5.5	5.7	4.5
	Iced	70.3	20.4	2.10	6.2	6.2	6.4	4.5
3rd	35	62.0	12.3	2.43	3.9	4.1	4.3	3.8
	50	61.4	11.6	2.57	3.8	3.5	4.0	3.6
	70	61.0	11.5	2.84	3.5	3.0	3.5	3.0
	88	59.4	10.6	3.31	3.2	2.6	3.0	2.6
	Iced	62.5	12.3	2.58	3.9	3.2	3.4	3.0
L.S.D.		1.24	1.06	0.183	0.42	0.48	0.41	0.59
F value		1.06	2.83	2.18	2.01	1.69	1.77	1.54

TABLE II—(*Concluded*)

Days	Variety	Objective Measures: Moisture (Per Cent)	Objective Measures: Succulometer (Cc)	Objective Measures: Pericarp (Per Cent)	Organoleptic Measures: Raw Grade	Organoleptic Measures: Succulence	Organoleptic Measures: Skin Character	Organoleptic Measures: Flavor
2 × 4—Duration of Storage by Varieties								
0	Seneca Chief	73.0	21.7	1.70	7.0	7.6	7.6	6.3
	G×B	69.3	18.5	1.67	6.6	6.3	6.7	6.4
	Ioana	69.8	18.8	2.02	6.6	7.7	7.1	5.6
1	Seneca Chief	71.5	20.1	2.02	6.9	6.6	7.1	5.0
	G×B	68.0	17.4	2.11	5.9	5.5	6.3	5.1
	Ioana	68.4	17.0	2.24	6.1	6.0	6.3	4.8
3	Seneca Chief	71.1	18.5	2.02	6.2	6.1	6.6	5.3
	G×B	66.3	15.6	2.24	5.1	5.2	5.6	4.5
	Ioana	67.3	15.5	2.39	5.1	5.0	5.1	4.4
5	Seneca Chief	70.2	18.5	2.19	5.7	5.9	5.9	4.3
	G×B	65.2	16.0	2.62	4.5	4.5	4.8	3.5
	Ioana	66.3	14.8	2.62	4.5	4.3	4.6	3.9
7	Seneca Chief	70.2	18.6	2.47	5.0	5.1	5.1	3.5
	G×B	64.9	15.2	2.72	4.2	4.2	4.5	3.6
	Ioana	66.6	15.0	2.96	4.5	4.6	4.5	3.5
	L.S.D.	1.24	1.06	0.183	0.42	0.48	0.41	0.59
	F value	0.91	0.63–	2.31	7.36	2.78	3.04	2.17
3 × 4—Temperature of Storage by Varieties								
Degrees F	Variety							
35	Seneca Chief	71.4	20.2	1.81	6.6	6.9	7.1	5.8
	G×B	67.5	17.8	2.00	5.7	5.8	6.2	5.4
	Ioana	68.3	17.1	2.10	5.9	6.3	6.3	5.5
50	Seneca Chief	71.4	19.3	1.98	6.2	6.6	6.9	5.3
	G×B	66.2	16.0	2.14	5.2	5.2	5.7	4.9
	Ioana	68.1	16.5	2.34	5.5	5.7	5.9	5.0
70	Seneca Chief	70.8	18.8	2.28	5.8	6.0	6.2	4.5
	G×B	65.8	15.5	2.42	4.9	4.7	5.3	4.3
	Ioana	67.4	15.0	2.62	5.2	4.9	5.0	3.6
88	Seneca Chief	70.1	18.5	2.42	5.6	5.6	5.7	4.2
	G×B	64.9	14.9	2.72	4.6	4.7	5.1	4.1
	Ioana	65.5	14.6	2.95	4.4	4.6	4.7	3.7
Iced	Seneca Chief	72.4	20.7	1.92	6.6	6.3	6.4	4.5
	G×B	69.3	18.5	2.08	6.0	5.3	5.6	4.3
	Ioana	69.0	18.0	2.23	5.9	5.7	5.7	4.3
	L.S.D.	1.24	1.06	0.183	0.42	0.48	0.41	0.59
	F value	1.72	1.09–	0.64–	1.00	0.88–	0.90–	0.98–

varieties, however, there is a very significant difference between the two white varieties as measured by the objective methods, but no significant difference as measured by the organoleptic methods, thus indicating that the factor of varieties is very important in reducing what might otherwise be a very high correlation. On the average, it appears that the Country Gentleman variety may contain considerably less moisture, a lower succulometer value, and a higher pericarp content, and yet rate equal to the Narrowgrain variety organoleptically.

Thus, in summarizing the main effects of the four variables, it appears that the factor of date of harvest is by far the most important

factor affecting objective values of moisture and succulometer, and organoleptic values for raw grade, succulence and skin character. The duration of storage is also important, but in its effect on pericarp content and organoleptic evaluation of flavor it approaches in importance the effect of date of harvest. The effect of temperature is generally less important than that of duration of storage. The varietal effect is displayed primarily among varieties of white corn where the Country Gentleman variety may equal Narrowgrain Evergreen organoleptically, but appears considerably poorer as measured objectively.

The interactions (that is, the simultaneous effect of more than one of the above main effects) for the yellow samples are presented in Table II, and those for the white varieties in Table III. Although many of the interactions are significant, only the important ones will be discussed. The interaction between dates of harvest and duration of storage, for example, exerts considerable effect on the raw grades

TABLE III—SWEET WHITE CORN—EFFECT OF VARIETIES, DATE OF HARVEST, DURATION AND TEMPERATURE OF STORAGE, ON OBJECTIVE AND ORGANOLEPTIC MEASUREMENTS OF QUALITY FACTORS (COLLEGE PARK, 1948)

	Objective Measures			Organoleptic Measures			
	Moisture (Per Cent)	Succulometer (Cc)	Pericarp (Per Cent)	Raw Grade	Succulence	Skin Character	Flavor
Main Order Effects							
1. *Date of Harvest*							
1st harvest	71.9	19.6	2.71	6 98	6.45	6.07	4.89
2nd harvest	64.4	14.1	3.95	4.56	4.29	3.60	3.45
L.S.D.	0 67	0.63	0.12	0 22	0.19	0.27	0 26
F value	503.95	307.53	462.24	462.09	534.78	343.22	121.62
2. *Duration of Storage (Days)*							
0	71.4	19.4	2.77	7.31	7.10	6.70	6.20
1	69.0	17.2	3.09	6 42	6.05	5.59	4.42
3	68.2	16.1	3.17	5.42	5.36	4.81	4.22
5	66.3	15.7	3.89	4.89	4.06	3.42	3.02
7	66.6	15.8	3.74	4.72	4.27	3.67	2.99
L.S.D.	1.06	1.00	0 18	0.36	0 29	0.42	0.41
F value	20.84	19.18	52.58	76.20	146.27	83.54	80.51
3. *Temperature of Storage (Degrees F)*							
35	68 3	17.1	2.85	6.09	6.01	5.68	4.96
50	68.6	16.5	3.02	6.08	5.94	5.39	4.66
70	68.0	16.8	3.64	5.66	4.95	4.36	3.70
88	66.2	14.9	4.18	4.59	4.28	3.82	3.27
Iced	69.6	19.0	2.98	6.40	5.66	4.94	4.26
L.S.D	1.06	1.00	0.18	0.36	0.29	0.42	0.41
F value	11.03	17.42	76.10	31.53	49.84	25.74	22.21
4. *Varieties*							
Country Gentleman	66.3	15.9	3.62	5.72	5.32	5.00	4.05
Narrowgrain Evergreen	69.9	17.9	3.05	5.80	5.41	4.68	4.29
L.S.D.	0.67	0.63	0.12	0.22	0.19	0.27	0.26
F value	117.05	40.41	95.47	0.34	0.82	5.82	3.24

TABLE III—(*Continued*)

Harvest	Days	Objective Measures			Organoleptic Measures			
		Moisture (Per Cent)	Succulometer (Cc)	Pericarp (Per Cent)	Raw Grade	Succulence	Skin Character	Flavor
2 × 4—Duration of Storage by Varieties								
0	Country Gentleman	68.4	19.1	3.02	7.12	7.10	6.90	6.00
	Narrowgrain Evergreen	72.4	19.8	2.53	7.50	7.10	6.50	6.40
1	Country Gentleman	67.0	15 4	3.50	6.35	5.92	5.77	4.44
	Narrowgrain Evergreen	72 1	19.0	2.68	6 38	6.18	5.40	4.40
3	Country Gentleman	66.6	15.1	3.30	5.62	5.76	5.18	4.24
	Narrowgrain Evergreen	69.8	17 2	3 05	5 22	4.96	4.44	4.20
5	Country Gentleman	64.3	14.4	4.37	4.89	3.74	3.24	2 60
	Narrowgrain Evergreen	68.3	16.9	3.42	4.97	4.38	3 60	3.44
7	Country Gentleman	65.3	15.3	3 89	4.73	4 10	3 90	2 98
	Narrowgrain Evergreen	68 0	16.4	3.58	4.71	4.43	3.44	3 00
	L S.D.	1.50	1.41	0.26	0 50	0 42	0 30	0.29
	F value	0.68	2 74	5.94	1 41	6.82	1.90	1.73
3 × 4—Temperature of Storage by Varieties								
Degrees F	Variety							
35	Country Gentleman	66.0	15.6	3 09	6.02	5.92	5.87	4 84
	Narrowgrain Evergreen	70 6	18.5	2.61	6 16	6 10	5 48	5.08
50	Country Gentleman	66.6	15.3	3.33	5.99	5.89	5.58	4.44
	Narrowgrain Evergreen	70.6	17.7	2.71	6.17	5.98	5.20	4.88
70	Country Gentleman	66.0	15.7	4 03	5 56	4 83	4 42	3 52
	Narrowgrain Evergreen	70.0	17.9	3.25	5 75	5.07	4.30	3 88
88	Country Gentleman	65.0	14 4	4 41	4.67	4.46	4 06	3.26
	Narrowgrain Evergreen	67.3	15.4	3.95	4.50	4.10	3.58	3.28
Iced	Country Gentleman	67.9	18.2	3 21	6 40	5 52	5.06	4.20
	green	71.2	19 8	2 74	6.39	5.80	4.82	4.32
	L.S.D.	1.50	1.41	0.26	0 50	0 42	0 30	0.29
	F value	1.43	1.07	1 13	0.39	1 60	0 25	0 35

TABLE III—(*Concluded*)

Days	Variety	Objective Measures			Organoleptic Measures			
		Moisture (Per Cent)	Succulometer (Cc)	Pericarp (Per Cent)	Raw Grade	Succulence	Skin Character	Flavor
				Interactions				
2 × 3—Duration by Temperature of Storage								
0	35	70.7	19.4	2.77	7.31	7.10	6.70	6.20
	50	70.7	19.4	2.77	7.31	7.10	6.70	6.20
	70	70.7	19.4	2.77	7.31	7.10	6.70	6.20
	88	70.7	19.4	2.77	7.31	7.10	6.70	6.20
	Iced	70.7	19.4	2.77	7.31	7.10	6.70	6.20
1	35	67.9	17.1	2.89	6.56	6.05	6.03	5.40
	50	69.9	17.4	2.86	6.72	6.13	5.85	4.60
	70	69.4	16.4	3.02	6.30	5.82	5.20	3.90
	88	68.4	16.8	3.62	6.24	5.95	5.15	3.80
	Iced	69.6	18.4	3.05	6.50	6.30	5.70	4.40
3	35	68.3	16.2	2.71	5.80	6.25	5.85	5.20
	50	68.0	15.7	2.90	5.90	6.30	5.55	5.20
	70	67.7	16.2	3.48	5.26	4.70	4.25	3.60
	88	67.4	13.7	4.00	4.17	4.10	3.50	2.80
	Iced	69.5	19.0	2.78	5.98	5.45	4.90	4.30
5	35	67.4	16.7	3.17	5.62	5.05	4.30	3.80
	50	66.8	15.2	3.35	5.24	5.00	4.30	3.80
	70	66.8	16.1	4.35	4.98	3.55	2.90	2.40
	88	62.3	12.3	5.31	2.60	2.05	1.85	1.80
	Iced	68.4	18.1	3.31	6.04	2.15	3.75	3.30
7	35	67.4	16.0	2.71	5.16	5.60	5.50	4.20
	50	67.8	14.9	3.22	5.22	5.15	4.55	3.50
	70	65.6	16.0	4.58	4.46	3.56	2.75	2.40
	88	62.3	12.2	5.20	2.60	2.20	1.90	1.75
	Iced	69.9	20.2	2.98	6.16	4.80	3.65	3.10
	L.S.D.	2.57	2.23	0.41	0.80	0.66	0.94	0.92
	F value	2.58	2.49	10.1	5.26	8.05	3.03	1.89

where prolonged storage is far more detrimental for material harvested at a very young stage of maturity than for older corn.

The simultaneous effect of duration and temperature of storage is illustrated in Fig. 1. It may be readily seen that, in general, the moisture content, succulometer values and all of the organoleptic values decrease, while pericarp content increases with increasing duration and temperature of storage. For example, the flavor of samples held for 1 day at 88 degrees F, was reduced to the same extent as the flavor of samples held under ice at 35 degrees F as long as 7 days. For the moisture and succulometer data especially, there appears to be a point of equilibrium beyond which there is no further reduction. This is in agreement with the observations of Appleman (2) who found that sugar content in stored sweet corn decreases to not less than 40 per cent of the original value, but reaches that point more rapidly when stored at high temperatures than when stored at low temperatures.

The icing treatment deserves special comment. Apparently the objective measurements of moisture and succulometer and the raw grade values indicate that there is a slight loss of succulence in iced corn during the first 3 days of storage. This loss is roughly equivalent to that obtained under 35 degrees F storage. Beyond that point, however,

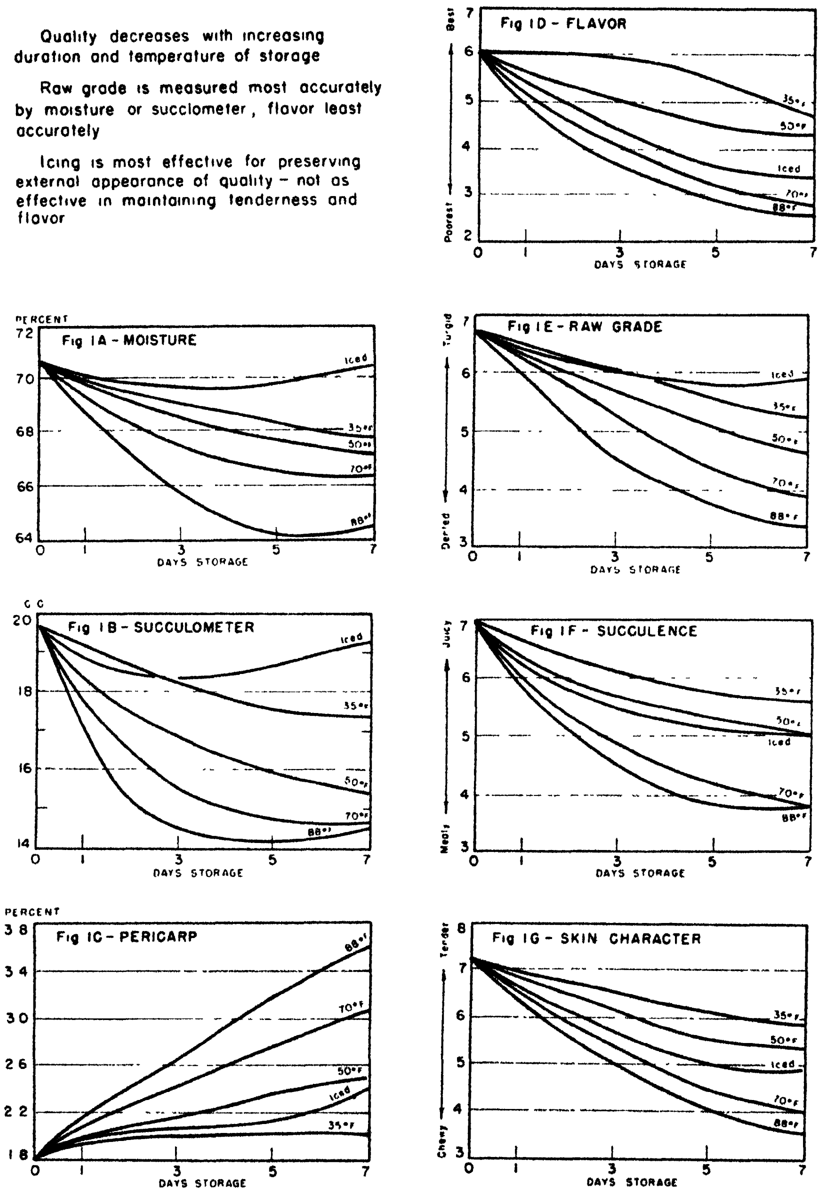

FIG. 1. Effect of duration and temperature of storage on objective and organoleptic measures of quality of Golden sweet corn.

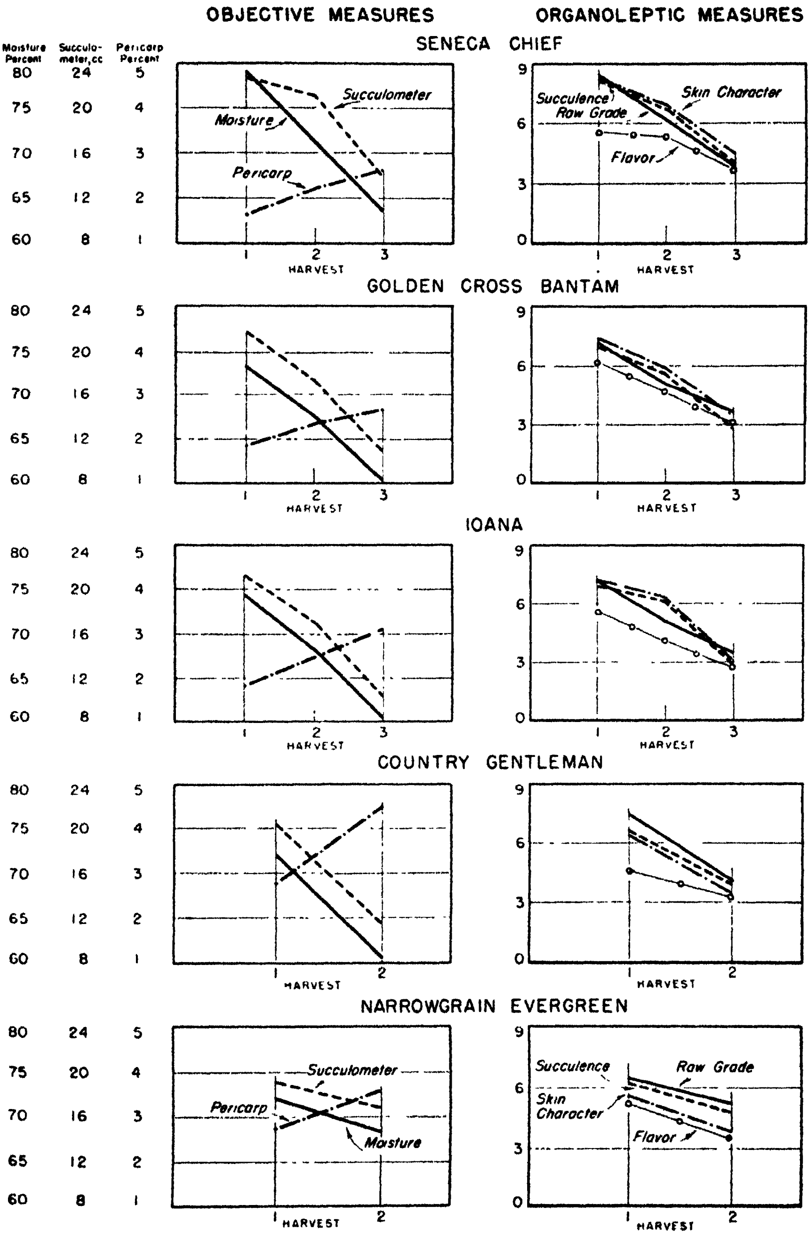

Fig. 2. Effect of variety and date of harvest on objective and organoleptic measures of quality of sweet corn.

iced corn seems to increase in succulence as measured by moisture content or succulometer. Pericarp content and the organoleptic ratings, however, indicate that the icing treatment is approximately equivalent to 50 degrees F storage, and in respect to flavor, perhaps even less than that. This icing treatment, therefore, is undoubtedly another factor which decreases the degree of correlation between some of the objective and organoleptic tests.

The interactions for the white corn data are generally similar to those of the golden corn except for the interactions of dates of harvest by varieties, where there is extremely high significance for all of the objective measures and the raw grade measurements, but considerably less for the organoleptic measures for succulence and skin character, and no significant difference for flavor of white varieties (Table III). Thus, whereas there is a tremendously large difference in moisture content of the two white varieties at the second harvest, there is only a moderate difference in the organoleptic determinations for succulence and skin character, and no difference whatsoever in flavor. It may be concluded from these data also that the Country Gentleman variety may contain considerably less moisture and more pericarp, and yet be considered equal to Narrowgrain Evergreen organoleptically. These varietal differences are illustrated graphically in Fig. 2. It may be seen, for example, that compared to moisture and succulometer values, the pericarp content of Seneca Chief is relatively low, and somewhat higher in Golden Cross Bantam; it is rather high in Ioana and Narrowgrain Evergreen, and extremely high in Country Gentleman.

Thus, it appears that the varietal factor, either alone or in interaction with other factors, is largely responsible for some of the poor correlations. When correlations were calculated for the golden varieties separately (Table IV), there was a general improvement in the degree

TABLE IV—GOLDEN SWEET CORN—CORRELATION COEFFICIENTS BETWEEN OBJECTIVE AND ORGANOLEPTIC EVALUATIONS OF QUALITY FACTORS*

Evaluation	Objective			Organoleptic			
	Moisture (Per Cent)	Succulometer (Cc)	Pericarp (Per Cent)	Raw Grade**	Succulence†	Skin Character†	Flavor†
Moisture (per cent)	—	0.92	0.77	0.95	0.88	0.88	0.68
Succulometer (Cc)	0.92	—	0.76	0.88	0.90	0.89	0.75
Pericarp (per cent)	0.77	0.76	—	0.80	0.81	0.84	0.77
Raw Grade**	0.95	0.88	0.80	—	0.87	0.89	0.78
Succulence†	0.88	0.90	0.81	0.87	—	0.98	0.83
Skin Character†	0.88	0.89	0.84	0.89	0.98	—	0.87
Flavor†	0.68	0.75	0.77	0.78	0.83	0.87	—

*Correlation coefficients higher than 0.21 are significant at the 1 per cent level.
**Determined from a calculation of grades as provided by United States Department of Agriculture grader for raw corn.
†Provided by a panel of judges who scored each sample for the three quality factors.

of correlation, and the organoleptic ratings for skin character and succulence became practically identical (0.98). The correlations between moisture or succulometer, and pericarp, however, were still low, indicating that such factors as the icing treatment were still present to

reduce the correlation. The correlations between all the objective tests and the organoleptic test for flavor also remained low. This may be explained by the fact that some of the extremely young samples were graded lower for flavor than other samples which were somewhat more mature. Also, the storage conditions were relatively more important in their effect on flavor than they were on the other tests.

The correlations for white corn in Table V were not improved materially. In fact, some of the correlations for the white corn alone

TABLE V—WHITE SWEET CORN—CORRELATION COEFFICIENTS BETWEEN OBJECTIVE AND ORGANOLEPTIC EVALUATIONS OF QUALITY FACTORS*

Evaluation	Objective			Organoleptic			
	Moisture (Per Cent)	Succulometer (Cc)	Pericarp (Per Cent)	Raw Grade**	Succulence†	Skin Character†	Flavor†
Moisture (per cent)	--	0 83	0.84	0 89	0.79	0.74	0.62
Succulometer (cc)	0 83	--	0.79	0 90	0 76	0.84	0.61
Pericarp (per cent)	0.84	0 79	-	0.82	0 84	0.73	0.75
Raw Grade**	0 89	0.90	0.82	- -	0.91	0.89	0.83
Succulence†	0.79	0 76	0 84	0 91	——	0.96	0.87
Skin Character†	0 74	0.84	0.73	0 89	0.96	--	0 89
Flavor†	0 62	0.61	0 75	0 83	0 87	0.89	——

*Correlation coefficients higher than 0 25 are significant.

**Determined from a calculation of grades as provided by United States Department of Agriculture grader for raw corn.

†Provided by a panel of judges who scored each sample for the three quality factors.

are lower than those for all of the corn samples. This indicates that the varietal factor does not necessarily depress the correlation because of differences between yellow and white varieties, but among the white varieties themselves, where the Country Gentleman type apparently behaves differently from the larger kernel types.

SUMMARY AND CONCLUSIONS

Two hundred and sixty-nine samples of sweet corn covering five varieties, three dates of harvest, five durations and five temperatures of storage, including an icing treatment, were analyzed for moisture content, pericarp content, and succulometer values. These objective values were correlated with organoleptic determinations of the raw and frozen corn, with the following conclusions:

1. The succulometer and moisture tests may be used interchangeably, and are very satisfactory in estimating the quality of the raw corn as it appears to consumers before cooking. After cooking, these tests were found to be good indicators of succulence and skin character, but not of flavor.
2. The pericarp test is inferior to the above as an indicator of raw appearance or succulence, but equal or perhaps slightly better for predicting skin character and flavor.
3. The factor of date of harvest is first in importance in determining objective values of moisture or succulometer, and organoleptic evaluations of raw grade, succulence and skin character.
4. The factor of duration of storage had relatively less effect on moisture and succulometer values than on pericarp or organoleptic

evaluations. For pericarp and flavor, the effect of prolonging the duration of storage was almost as severe as delaying the date of harvest.

5. Effect of increasing temperature of storage was not as severe as increasing duration of storage on the reduction of quality of sweet corn.

6. Varietal differences were found primarily among the white varieties where Country Gentleman samples, ranking equally with the other varieties in the organoleptic tests, appeared inferior according to the objective tests.

7. The icing treatment was very effective in retaining succulence but was equivalent to about 60 degrees F storage in its effect on flavor retention.

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Physiological Changes in Asparagus After Harvest[1]

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Developments in the marketing processes of vegetables which seek to improve the quality of the consumer product must be based on a thorough knowledge of the nature and extent of the changes taking place between the time of harvest and the time of consumer utilization. Excellent information on these changes in asparagus is found in the early studies of Bitting (3), Morse (6) and Bisson *et al* (2). More recent reports on the ascorbic acid content of asparagus during storage are those of Platenius (7) and Kays (4).

The present paper reports the results obtained in a series of asparagus storage tests, with particular emphasis on changes in ascorbic acid content, fibrousness, and color, as affected by the temperature and duration of the storage period.

Materials and Methods

The experimental data were obtained from five different lots of asparagus in 1948. All of the asparagus was harvested as "green" stock, in accord with the usual commercial practice of the area, with the minimum length of the spear above ground when harvested about 6 inches. The lots are designated as follows:

Lot 1:—Harvested April 9 from the Plant Research Farm of the University of Maryland. The spears were trimmed to 8 inches in length, and stored within 3 hours after harvest in constant temperature cabinets at 32, 40, 50, and 70 degrees F with the butt ends in water. Total solids and ascorbic acid content were obtained on samples taken from each lot after 0, 1, 4, and 8 days storage. The spears were snapped upon removal from storage and the snapped tip used for analysis.

Lot 2:—Harvested April 14 from the Plant Research Farm and handled the same as lot 1 except that samples were taken for analysis after 0, 1, 3, 5, and 8 days storage.

Lot 3:—Harvested April 17 from Plant Research Farm and stored at same temperatures as lots 1 and 2 and analyzed after 0, 1, 3, and 7 days storage. Determinations of total solids, ascorbic acid, color, and fiber were made on 1¼ inch segments of the spears and on the snapped tip.

Lot 4:—Harvested May 5 by a commercial grower in Maryland. Brought into the laboratory the following day, cut to 9 inch length and stored at 32, 50, 68, and 86 degrees F. Samples were analyzed after 0, 2, 4, and 6 days storage. Total solids, ascorbic acid, color, and fiber determinations, and pressure readings were obtained on the 4½ inch tip, the 4½ to 6 inch cut, the 6 to 7 inch cut, and the snapped tip.

Lot 5:—Harvested May 13, and placed in storage at 32 and 50 degrees F, and at room temperature on the afternoon of the same day.

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This lot had been graded by the grower into two size grades, which were analyzed separately throughout the test. The bunches were stored in crates without wet moss or other source of moisture. Total solids, ascorbic acid, color, fiber, and pressure determinations were made after 0, 36, 84, and 132 hours storage. Spear segments analyzed were the 4¼ inch tip, the 4¼ to 5¾ inch cut, the 5¾ to 7¼ inch cut, the 7¼ inch to base cut, and the snapped tip.

Total solids were determined by blending 100 grams of segments with an equal weight of distilled water in the Waring blendor for 5 minutes. An aliquot of the blend was weighted into a tared porcelain moisture dish and dried in a vaccuum oven at 70 degrees C overnight.

Ascorbic acid was determined by the indophenol dye-xylene extraction method of Robinson and Stotz (8), using a Beckman spectrophotometer of a Leitz photoelectric colorimeter for reading the color values.

Fiber determinations were made by the method given by Smith and Kramer (9).

Color determinations and the pressure readings were obtained by the methods described by Kramer *et al* (5).

The term "snapped tip" as used in this paper refers to the tip portion of the spear obtained when the spear is broken by pressure on the ends with the hands. The significance of this point with respect to quality factors in the asparagus spear has been considered by Smith and Kramer (9) and the employment of "snapping" as a harvesting method has been suggested by Barrons (1).

Results

Weight Change:—When asparagus spears are stored with the cut surfaces of the butt ends in contact with moisture, water is taken up into the spear resulting in an increase in the fresh weight of the material. The effect of temperature and length of storage upon the change in weight of asparagus stored with the butt ends in water is given in Table I. The uptake of water resulted in a steady increase in weight for the 32, 40 and 50 degrees F storage temperatures, the increase reaching 20 per cent at 40 and 50 degrees F. At 32 degrees F the water uptake was about half that at 40 degrees F. At 70 degrees F storage the water uptake was extremely rapid during the first day of storage but thereafter there was a net loss of weight so that at the end of 8 days

TABLE I—Asparagus (Gain in Weight During Storage, Lot 2)

Treatment	Per Cent Gain in Weight After Storage of.			
	1 Day	3 Days	5 Days	8 Days
32 degrees—Snapped	0 9	9.3	7.1	11 0
Unsnapped	0 5	2.8	3 9	6.9
40 degrees—Snapped	1.1	12.8	16.9	20.8
Unsnapped	2.7	10.0	13.5	17.4
50 degrees—Snapped	4.5	14.9	13.8	20.4
Unsnapped	3.1	9.4	15.4	17 1
70 degrees—Snapped	19.3	—	12 5	-5.4
Unsnapped	15.3	11 7	-.5	-21 6

storage there had occured a loss of more than 20 per cent of the initial weight.

The loss in weight at the higher temperature probably results from a blocking of the conducting vessels at the cut surfaces of the spears, preventing the uptake of water equal to the loss by transpiration.

When the spears were stored dry as in lot 5, there was a decrease in weight, amounting to about 3.5 per cent after 6 days storage at 32 or 50 degrees F and 5.5 per cent after 2 days at room temperature.

Total Solids:—As the spears in storage increase in fresh weight due to the uptake of water it would be expected that the per cent total solids content would decrease. This change in total solids is shown in Table II. The per cent solids decreased with continued storage and with increasing temperature, with the exception that the per cent solids for the lot stored at 70 degrees F showed a sharp increase after storage of 7 days.

TABLE II—EFFECT OF TEMPERATURE AND LENGTH OF STORAGE UPON THE TOTAL SOLIDS CONTENT OF FRESH ASPARAGUS SPEARS (LOT 3)

Storage Temperature (Degrees F)	Per Cent Total Solids After Storage Period of				Mean of Temperatures
	0 Days	1 Day	3 Days	7 Days	
32	10.07	9.27	8.83	8.63	9.20
40	10.07	9.15	8.60	8.08	8.98
50	10.07	8.97	8.75	7.48	8.82
70	10.07	8.17	7.28	10.65	9.04
Mean of storages	10.07	8.89	8.37	8.71	—

L.S.D. per cent: Between individual readings - 1.20.
Between temperature and storage means - .60.

The increase in fresh weight and decrease in per cent total solids found are in accord with the results obtained by Bisson *et al* (2).

The per cent total solids in the spears decreased from the tip toward the base (Table III). The 1¼ inch tips in lot 3 contained 12.96 per cent solids as compared with 6.98 per cent solids content of the 2¾ to 5 inch cut from the same spears. The data obtained from lot 4 indicates that the decreasing trend may not extend farther than 6 inches from the tip of the spear.

Ascorbic Acid:—In all of the tests it was found that an increase in the storage temperature or an increase in the length of storage was reflected quite sharply in a lower ascorbic acid content of the material. These effects are shown in Table IV. The loss of ascorbic acid at 32 degrees F storage is quite marked, in that the final content was about two-thirds that of the initial content in lots 2 and 3. Storage at 32 degrees in all tests showed a lesser loss of ascorbic acid than 40 degrees F storage, but the differences are significant in only lot 2. Differences between 32 and 50 degrees F storage and 50 and 70 degrees F storage are in all cases significant with the greater loss occuring at the higher temperature.

The lower mean values for ascorbic acid shown by lot 4 probably arise from two factors; first, a 7-inch length of spear was analyzed in this lot in contrast to the 5-inch lengths analyzed in lots 1, 2, and 3;

TABLE III—Distribution of Total Solids, Ascorbic Acid and Chlorophyll in the Asparagus Spear

Segment of Spear	Per Cent Total Solids	Ascorbic Acid Mg/100 Gm	Chlorophyll Mg/Kg
Lot 3			
1¼ inch tip	12.96	69.9	247.7
1¼ to 2½ inch cut	9.09	45.8	146.1
2½ to 3¾ inch cut	7.51	35.6	90.3
3¾ to 5 inch cut	6.98	31.2	62.9
0 to 5 inch spear	8.68	42.8	122.4
Snapped tip	8.84	43.1	128.0
L.S.D. (5 Per cent level)	.74	5.3	18.3
Lot 4			
4½ inch tip	8.68	27.6	130.6
4½ to 6 inch cut	6.29	15.0	55.6
6 to 7 inch cut	6.66	13.4	46.4
0 to 7 inch spear		21.1	121.6
Snapped tip	7.75	26.7	95.3
L.S.D. (5 per cent level)	.40	1.7	8.3
Lot 5			
4¼ inch tip		34.5	118.8
4¼ to 5¾ inch cut		19.1	60.0
5¾ to 7¼ inch cut		16.6	49.6
7¼ to 9 inch cut		15.1	41.7
0 to 7¼ inch spear		25.7	85.1
Snapped tip		31.8	94.5
L.S.D. (5 per cent level)		1.1	7.8

and second, there was a delay of 24 hours between time of harvest and the initial analyses in lots 4 as compared with an interval of only a few hours in the other lots.

The loss in ascorbic acid shown in the fresh weight basis is real and not affected greatly by the accompanying decrease in total solids. For example, calculation of ascorbic acid on a dry weight basis for lot 3 after a storage period of 7 days, shows 45 per cent loss at 32 degrees F, 59 per cent loss at 50 degrees F and 84 per cent loss at 70 degrees F. Comparable losses on a fresh weight basis for the same storage conditions are 52, 68, and 85 per cent. Similar comparisons with other lots gave like results, showing the same general trend in ascorbic acid levels on either basis, but with somewhat less accentuated storage losses where calculated on a dry weight basis.

In all of the tests in which there was an analyses of segments of the asparagus spear, there was found a well defined gradient in ascorbic acid content from the tip toward the base (Table III).

The data of lot 5 permit a comparison of the ascorbic acid content of large and small spears. Although the smaller spears were found to have a statistically significantly higher content, 24.7 as compared with 22.9 mg per 100 gram, the difference is not important in view of the much greater effects of length and temperature of storage and the portion of spear analyzed.

A statistical summary of the ascorbic acid data is given in Table V. The values for the main effects in all of the tests were highly significant. The significant interaction between temperature and length of storage found in lots 3, 4, and 5 results from the relatively greater effect on ascorbic acid loss of the higher temperatures after prolonged storage.

TABLE IV—EFFECT OF TEMPERATURE AND DURATION OF THE STORAGE PERIOD UPON THE ASCORBIC ACID CONTENT OF FRESH ASPARAGUS (FRESH WEIGHT BASIS)

Storage Temperature (Degrees F)	Ascorbic Acid (Mg/100 Gm) After Storage of:				Mean of Temperature
	0 Days	1 Day	4 Days	8 Days	
			Lot 1		
32	54.1	53 4	32.2	30.6	42 6
40	54.1	50 2	26 4	30.7	40.4
50	54.1	50.2	25 7	23 1	38 3
70	54.1	32.2	16.9	13.9	29.3
Mean of storage	54.1	46 5	25 3	24 6	——

L.S.D. (5 per cent level) Between individual readings—12.4
Between temperature and storage means—6.2.

	0 Days	1 Day	3 Days	5 Days	8 Days	Mean of Temperature
			Lot 2			
32	54 1	50 7	47.8	38 4	22 4	43.3
40	54 1	52 2	36 4	28 1	16 8	37.5
50	54 1	51 0	33 2	32 6	13 7	37.9
70	54 1	38.9	19.7	17 0	3.3	26 6
Mean of storage	54 1	48 0	35 5	29 0	14 0	——

L.S D. (5 per cent level) Between individual readings - 10.0.
Between storage means- -7.5.
Between temperature means- 5 3

	0 Days	1 Day	3 Days	7 Days	Mean of Temperature
			Lot 3		
32	65 2	66 0	49 3	31.3	53 0
40	65.2	60 2	47.0	26.2	49.6
50	65 2	49 2	36 2	20.8	42 8
70	65 2	38 1	20 7	10 0	33 5
Mean of storage	65 2	53 3	38 3	22 1	--

L.S D. (5 per cent level) Between individual readings - 8.6.
Between temperature or storage means—4.3.

	0 Days	2 Days	4 Days	6 Days	Mean of Temperature
			Lot 4		
32	24 7	22.0	21.7	18.4	21.7
50	24.7	17.0	12.6	10.5	16.2
68	24.7	11 0	10.5	9.8	14.0
Mean of storage	24.7	16 7	14.9	12.9	——

L.S.D. (5 per cent level) Betweem individual readings--2.6.
Between storage means—1 5.
Between temperature means—1.3.

The nature of the interaction between length of storage and segment of spears, although significant in all cases, is not easily determined and probably is not of important magnitude. A similar situation exists in the significant interaction found between temperature of storage and segment of spear in lots 4 and 5. A relatively greater loss of ascorbic

TABLE V—SUMMARY OF "F" VALUES OBTAINED IN VARIANCE ANALYSIS OF ASCORBIC ACID CONTENT DATA WITH ASPARAGUS (ON FRESH WEIGHT BASIS)

	Lot 1	Lot 2	Lot 3	Lot 4	Lot 5
Main effects:					
1. Length of storage	137.43**	87.03**	161.44**	109.57**	182.20**
2. Temperature of storage	20.82**	20.80**	34.14**	87.24**	18.89**
3. Segment of spear	—	—	55.91**	96.72**	481.37**
4. Size of spear	—	—	—	—	30.09**
Interactions:					
1 × 2	3.06	1.78	4.26**	11.72**	20.16**
1 × 3	—	—	2.17*	5.08**	2.38*
1 × 4	—	—	—	—	11.06**
2 × 3	—	—	1.03	2.82	2.91*
2 × 4	—	—	—	—	0.11
3 × 4	—	—	—	—	0.97

*Indicates significance at 5 per cent level.
**Indicates significance at 1 per cent level.

TABEL VI—EFFECT OF TEMPERATURE AND LENGTH OF STORAGE UPON COLOR OF FRESH ASPARAGUS (COLOR EXPRESSED AS MG CHLOROPHYLL PER KG FRESH WEIGHT)

Lot 3		Lot 4		Lot 5	
Storage (Days)	Color	Storage (Days)	Color	Storage (Days)	Color
0	149.2	0	124.2	0	87.6
1	144.0	2	128.7	1.5	77.4
3	134.4	4	62.7	3.5	74.6
7	103.9	6	43.9	5.5	60.3
L.S.D. (5 per cent level)	14.9		7.5	—	6.4
Temperature (Degrees F)	Color	Temperature (Degrees F)	Color	Temperature (Degrees F)	Color
32	142.8	32	92.1	32	77.1
40	140.2	50	87.1	50	72.8
50	127.4	68	90.5	—	—
L.S.D. (5 per cent level)	14.9	—	Not significant	—	Not significant

acid from the small spears in lot 5 during the storage period is reflected in the significant interaction between length of storage and size of spear in that lot.

Color:—The effects of temperature of storage and length of storage upon the color of asparagus as expressed quantitatively are shown in Table VI. In all three lots there was a significant loss of color during the storage, amounting in lot 3 to more than half of the original content and in the other two lots to about one-third. The effect of storage temperature was not important. Although all lots showed a general decrease in color with the higher temperatures, only in lot 3 were the differences significant. It would seem that increasing duration of storage resulted in a loss of chlorophyll, to a large extent independently of the storage temperature.

A definite color gradient from the tip to the base of the spear obtained in all lots (Table III). The heavy concentration of chlorophyll in the tips of the spears is shown in data of lot 3, in which the 1¼ inch tips contains 247.7 as compared with 146.1 mg per kg in the 1¼ to 2½ inch segment.

The size of spear comparison in lot 5 showed a significantly higher color value for the smaller spears, 81.6 as compared with 68.4 mg per kg for the large spears.

Interactions between the main effects were in most instances not significant. In lot 4 a significant interaction between storage period and segment of spear, indicated a relatively greater loss of color in the tip segments, but this trend is not borne out in the other two lots.

Fiber:—Since fibrousness of asparagus is perhaps the most important factor determining edible quality of the fresh or processed product, any change in the fiber content due to storage conditions is of interest. Table VII gives the data obtained from lot 4, showing that there is no significant effect of either length or temperature of storage upon the amount of fiber in the spears. In fact there seems to be trend toward a decrease in fiber content both with higher temperatures and with increasing storage.

TABLE VII—FIBER CONTENT OF FRESH ASPARAGUS AS AFFECTED BY STORAGE (DATA FROM LOT 4)

	On Fresh Weight Basis	On Dry Weight Basis	Organoleptic Rating*
Stored: (Days)			
0	298	----	7 00
2	293	4,260	7 57
4	286	4,420	6.97
6	270	4,110	6 08
L.S.D. (5 per cent level)	n s	n.s.	71
Stored at (Degrees F):			
32	236	4,800	6.76
50	187	3,940	6.85
68	166	4,060	7.09
L.S.D. (5 per cent level)	n s.	n s.	n s.
Segment of spear.			
4½ inch tip	44	480	9 11
4½ to 6 inch cut	184	2,910	6 49
6 to 7 inch cut	883	12,690	3.51
Snapped tip	66	960	8 51
L.S.D. (5 per cent level)	106	1,890	71

*Ratings decrease with increasing fibrousness of spears; basis of 1 to 10 Correlation coefficient between fiber content on fresh weight basis and organoleptic rating, $r = -.83$.

The results obtained with lot 5 (Table VIII) which was stored without having the butts of the spears in water, were similar. There was a statistically significant decrease in fiber occurring during the first part of the storage period and no significant difference between 32 and 50 degrees F storage.

The sharp gradient in fiber content of the spears from the tip to the base is also shown. The relation of this distribution to the quality of the marketable spears is given full consideration by Kramer *et al* (5).

The organoleptic ratings of fibrousness accompanying the fiber content data in Tables VII and VIII show no significant effect of temperature of storage in either lot, no effect of duration of storage in lot 5 and only a slight effect toward the end of the storage period in lot 4. The correlation coefficients of —.83 for lot 4 and —.91 for lot 5 between the fiber content and organoleptic ratings, indicate that the method of the fiber determination employed very closely reflects the degree of fibrousness determined organoleptically.

TABLE VIII—FIBER CONTENT OF FRESH ASPARAGUS AS AFFECTED BY STORAGE (DATA FROM LOT 5)

	Fiber Content (Mg/100 Gm Fresh Weight)	Organoleptic Rating*
Stored: (Days)		
0	484	6.89
1.5	325	6.84
3.5	361	6.85
6.5	315	6.87
L.S.D. (5 per cent level)	124	n.s.
Stored at (Degrees F):		
32	341	6.97
50	401	6.96
L.S.D. (5 per cent level)	n.s	n.s.
Segment of spear:		
4¼ inch tip	39	9.35
4¼ to 5¾ inch cut	91	7.70
5¾ to 7 inch cut	406	5.85
7 inches to base	948	2.53
L.S D. (5 per cent level)	124	.56
Size of spear:		
Small	351	7 07
Large	391	6.65
L S D. (5 per cent level)	n s	.35

*Ratings decrease with increasing fibrousness of spears; basis of 1 to 10.
Correlation coefficient between fiber content and organoleptic rating: r = -.91

Crude fiber by the official method was determined on a series consisting of 28 samples from lot 4. These values are listed along with the values obtained by the rapid method and the organoleptic ratings in

TABLE IX—FIBER CONTENT OF ASPARAGUS AS DETERMINED BY THE OFFICIAL AND RAPID METHODS (PER CENT FIBER ON FRESH WEIGHT BASIS)

Sample	Segment of Spear	Official Method	Rapid Method	Organoleptic Rating
1	4½ inch tips	0 058	0 02	9 5
2	4½ inch tips	0.071	0.02	8.5
3	4½ inch tips	0.060	0.01	9.5
4	4½ inch tips	0.054	0 02	7.8
5	4½ inch tips	0.054	0.03	9.2
6	4½ inch tips	0.075	0.04	9.7
7	4½ inch tips	0.063	0.05	9 2
8	4½ inch tips	0.073	0 04	9.2
9	4½ inch tips	0.058	0.07	9.2
10	Snapped tips	0.061	0.04	9.5
11	Snapped tips	0 065	0.23	6.8
12	Snapped tips	0.067	0.04	8.8
13	Snapped tips	0.080	0.13	7.7
14	Snapped tips	0.079	0.05	8.0
15	Snapped tips	0.068	0 05	6.8
16	Snapped tips	0.071	0.07	7.8
17	4½ to 6 inch cut	0.066	0.19	6.5
18	4½ to 6 inch cut	0.067	0.25	5.5
19	4½ to 6 inch cut	0.058	0 25	8.0
20	4½ to 6 inch cut	0.080	0.24	5.8
21	4½ to 6 inch cut	0.054	0.10	7.7
22	4½ to 6 inch cut	0.058	0.25	5.3
23	4½ to 6 inch cut	0.061	0.11	7.8
24	4½ to 6 inch cut	0.064	0.14	6.5
25	4½ to 6 inch cut	0.066	0.14	6.0
26	6 to 7 inch cut	0 088	0.94	2.2
27	6 to 7 inch cut	0.086	0.91	4.0
28	6 to 7 inch cut	0 083	0.48	4.3

Correlation coefficients from above data:
1. Between official and rapid method +.59
2. Between official method and organoleptic rating -.47
3. Between rapid method and organoleptic rating -.85

Table IX. The rapid method gives a much wider range of values, showing lower fiber values for the non-fibrous samples and higher values than the official method for the more fibrous samples.

The correlation coefficients given indicate a much better agreement of the rapid test with the organoleptic ratings.

The results obtained relative to the fiber content of asparagus during storage are at variance with the studies of Morse (6) and Bisson *et al* (2), who found a distinct increase in fiber associated with increasing duration and temperature of storage. The method of fiber determination probably accounts for the difference. The method of Smith and Kramer (9) which was used in the present tests is entirely physical in nature involving the mechanical separation of the fibrous vascular tissue washing after maceration in a Waring blendor. The crude fiber method used by the earlier workers separates fiber through the dissolution of non-fibrous material by the action of hot alkali and acid. It is believed that the rapid method used in the present tests more accurately reflects the organoleptic fibrousness of asparagus than does the official crude fiber method.

Pressure Readings:—The use of an instrument measuring the pressure required to cut the asparagus spear and the correlation of pressure readings with fiber content has been described by Kramer *et al* (5).

Table X gives a summary of the changes in pressure readings as affected by storage conditions. The readings increased significantly during the storage period of the three lots tested. The effect of temperature was not consistent, in lot 5 no difference obtained, in lot 3 storage at 80 degrees F resulted in higher readings than the lower temperatures, while in lot 4 readings decreased with increasing temperatures. How-

TABLE X—EFFECT OF LENGTH AND TEMPERATURE OF STORAGE AND SEGMENT UPON PRESSURE READINGS OF FRESH ASPARAGUS

Lot 3		Lot 4		Lot 5	
Storage (Days)	Pressure	Storage (Days)	Pressure	Storage (Days)	Pressure
0	4.26	0	8.78	0	7.45
1	5.31	2	8.33	1.5	8.55
3	4.98	4	9.15	3.5	7.84
7	6.58	6	9.87	5.5	8.45
L.S.D. (5 per cent level)	0.43	—	1.01	—	0.81
Temperature (Degrees F)	Pressure	Temperature (Degrees F)	Pressure	Temperature (Degrees F)	Pressure
32	5.04	32	9.68	32	8.09
40	5.11	50	8.52	50	8.05
50	5.29	68	8.89	—	—
70	5.10	—	—	—	—
80	5.90	—	—	—	—
L.S.D. (5 per cent level)	0.49	—	0.87	—	n.s.
Segment of Spear	Pressure	Segment of Spear	Pressure	Segment of Spear	Pressure
1¼ inch tip	3.02	4½ inch tip	5.89	4¼ inch tip	5.92
1¼ to 2½ inch cut	4.31	4¼ to 6 inch cut	8.68	4¼ to 5¾ inch	7.30
2½ to 3¾ inch cut	5.61	6 to 7 inch cut	14.73	5¾ to 7¼ inch	10.99
L.S.D. (5 per cent level) .	0.49	—	1.01	—	0.72

ever, these differences, although statistically significant, are relatively unimportant when compared to the great differences between the tip and basal portions of the spear.

The increase in pressure readings during storage may be related to the progressive lignification of the vascular elements as shown by Bisson *et al* (2). It is possible that lignification would increase the rigidity of the fibrous strands without increasing the amount of fiber as measured by the method used.

Summary

Asparagus spears increased in fresh weight and decreased in total solids content during storage. These changes were affected by the storage temperature.

Ascorbic acid content decreased rapidly with both increasing temperature and duration of storage. Approximately one-half of the original ascorbic acid content is lost after a week's storage at 32 degrees F. At 70 degrees F the loss may equal 90 per cent.

The color intensity (as measured by chlorophyll content) of the spears decreased during the storage period. Storage temperature had little or no effect on the disappearance of chlorophyll.

There was no significant change in the fiber content of the spears during storage. Pressure readings increased slightly during the storage period.

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Ascorbic Acid Content of Twenty-five Varieties of the Rutabaga (Brassica napobrassica)[1]

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ALTHOUGH the rutabaga is known to have excellent antiscorbutic properties (5,8,10), few data on the concentration of ascorbic acid in different varieties have been published. One report (9) lists the rutabaga as containing 36 mg ascorbic acid per 100 grams, but does not indicate the variety on which this figure is based. Chandler and Miller (4), studying the effects of boron on vitamin C content, report that under conditions of optimum boron supply samples of the Macomber variety grown in Maine and in Rhode Island contained 39.7 mg and 36.4 mg vitamin C per 100 grams, respectively. Samples of the variety Long Island Improved grown in Maine contained 49.0 mgs per 100 grams. Biester (3) studied eleven varieties and found the vitamin C content to vary from 29 mg in Laurentian to 62 mg in Wilhelmsberger.

As a part of adaptation tests of rutabagas in northern Minnesota, a study was made of the ascorbic acid contents of 25 varieties grown at two locations in 1947 and 1948. The present paper is a report on results of this study.

MATERIALS AND METHODS

In 1947, 25 varieties of rutabagas were grown at Castle Danger on the north shore of Lake Superior and at the North Central Experiment Station at Grand Rapids, Minnesota. Dates of seeding and harvest, respectively, were as follows: Castle Danger—May 29 and October 2, and Grand Rapids—June 17 and October 1. Each of the varieties were grown in single 18-foot rows with the rows spaced 3 feet apart.

In 1948, the same 25 varieties were seeded in two randomized blocks at each of the two locations, each plot consisting of a single 18-foot row. In 1948, the dates of seeding and harvest, respectively, were as follows: Castle Danger—May 27 and October 8, Grand Rapids—June 15 and October 7.

In both years plots were blocked and plants thinned to a spacing of 8 to 10 inches approximately 1 month after seeding. At harvest, four or five roots from each plot were selected at random and held in storage at 36 to 40 degrees F until ascorbic acid determinations could be made. With the exception of rotting in some lots from Grand Rapids in 1947, all samples remained firm and dormant throughout the storage period. Since McIntosh (6) has reported that the decrease in ascorbic acid content of dormant rutabaga roots during storage is

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slight, the ascorbic acid values obtained for the 25 varieties in this study should be comparable. In 1947, ascorbic acid determinations were begun on January 8 and were completed on March 6. In 1948, analyses were completed in the period from October 27 through December 14.

Ascorbic acid content was determined by means of the 2,6–dichlorophenolindophenol visual titration method (1). In order to determine the best method of sampling the rutabaga root, a study was made of the distribution of ascorbic acid in the root. Four samples were taken from single roots of each of three different varieties as follows: (a) skin, including about ⅛ inch of flesh, (b) a transverse slice cut from the upper one-third of the root, (c) a transverse slice cut from the center one-third of the root, and (d) a transverse slice cut from the lower one-third of the root. The ascorbic acid concentrations in 100-gram samples of each of these sections are given in Table I.

TABLE 1—Ascorbic Acid Content of 100-Gram Samples From Different Areas of Roots of Three Varieties of Rutabaga

Part of Root	Variety 1 (Mg)	Variety 2 (Mg)	Variety 3 (Mg)
Skin*	43.7	62.1	46 2
Upper one-third	43 7	61 8	46.3
Center one-third	43 9	62 1	46.4
Lower one-third	43.5	61 9	46 1

*Including ⅛ inch of flesh.

While it is apparent from the data in Table I that ascorbic acid is uniformly distributed throughout the root, all data reported in this paper are based on analysis of a 100-gram sample sliced transversely across the center section of the rutabaga root. Duplicate samples from two roots of each variety were analyzed and the data were averaged to give the values reported.

Experimental Results

The concentrations of ascorbic acid in the roots of the 25 rutabaga varieties grown at Castle Danger and Grand Rapids in 1947 and 1948 are given in Table II. Due to excessive rotting in nine of the varieties grown at Grand Rapids in 1947, the roots were discarded and no ascorbic acid determinations are reported for these samples.

Statistical analysis of the 1947 data on 16 varieties (using variety by location interaction as error) showed that the varieties differed significantly in ascorbic acid content while the location means did not differ. As shown in the third column of Table II, ascorbic acid concentration in the 16 varieties varied from 64 mg per 100 grams in Wilhelmsburger to 38 mg per 100 grams in Laurentian. The mean ascorbic acid contents of the varieties grown at Grand Rapids and at Castle Danger were identical being 48 mg per 100 grams.

In 1948, data were obtained for all 25 varieties at both locations. In order to determine if ascorbic acid concentration was associated with size (weight) of roots, the two roots of each lot analyzed were

TABLE II—ASCORBIC ACID CONTENT OF 100-GRAM SAMPLES OF ROOTS OF RUTABAGA VARIETIES GROWN AT TWO LOCATIONS IN 1947 AND 1948

Variety	1947 (Mg)			1948 (Mg)			Mean of Three Complete Tests (Mg)*
	Grand Rapids	Castle Danger	Mean	Grand Rapids	Castle Danger	Mean	
New Yellow Garden	53	59	56	82	55	69	66
Wilhelmsburger	59	70	64	77	49	63	65
Invicta	45	46	46	74	69	71	63
American Purple Top	50	53	52	70	62	66	62
Jumbo	—	50	—	81	49	65	60
Canadian Gem	58	42	50	75	57	66	58
Northwestern	50	55	52	63	51	57	56
Bangholm Herning	—	48	—	62	58	60	56
Purple Top	48	46	47	68	47	57	54
Lord Derby	63	56	60	59	47	53	54
Sutton's Bronze Top	—	43	—	64	50	57	53
Imperial	49	54	52	58	48	53	53
Selected Prize Elephant	39	45	42	62	46	56	51
Acadia	50	39	44	64	49	56	51
Purple King	—	49	—	65	40	52	51
Ditmar's Bronze Top	40	49	44	60	45	52	51
Perfection	40	44	42	64	43	53	50
Bangholm, U.B.C	—	38	—	62	46	54	49
Superlative	—	41	—	57	45	51	47
Laurentian	39	38	38	64	34	49	46
Monarch	46	40	43	57	39	48	45
F Special XXX	—	37	—	59	38	49	45
Sutton's Purple Top	—	28	—	60	43	51	44
Danish Giant	46	36	41	54	42	48	44
Golden Table Turnip	—	33	—	52	34	43	40
Mean of 16 varieties	48	48		66	49		
Mean of 25 varieties	—	46		64**	47**		
L.S.D. 5 per cent level	17	17	12	11	11	7	
L.S.D. 1 per cent level	23	23	16	14	14	10	

*Castle Danger, 1947, and Grand Rapids and Castle Danger, 1948.
**L.S.D. 1 per cent level between location means = 2.

weighed before sampling and the determinations on "large" and "small" roots were not combined. In the statistical analysis of the 1948 data, the total variance was apportioned as shown in Table III. The variances due to varieties and locations were significant at the 1 per cent level while the variances due to "sizes" and the interaction varieties x locations were significant at the 5 per cent level.

It is seen in Table II that the ascorbic acid concentrations in the 25 varieties tested ranged from a high of 71 mg per 100 grams in Invicta to a low of 43 mg per 100 grams in Golden Table Turnip. In 1948, the

TABLE III—ANALYSIS OF VARIANCE OF ASCORBIC ACID CONTENTS OF RUTABAGA VARIETIES GROWN IN 1948

Source of Variation	Degrees of Freedom	Mean Square
Replications	1	48.02
Varieties	24	415.83**
Locations	1	14,688.98**
Sizes	1	322.58*
Varieties × Locations	24	111.76*
Varieties × Sizes	24	35.57
Locations × Sizes	1	69.62
Varieties × Locations × Sizes	24	38.98
Remainder	99	57.00
Total	199	

*Variance significant at 5 per cent level.
**Variance significant at 1 per cent level.

location means differed significantly, the mean of varieties grown at Grand Rapids being 64 mg per 100 grams while the mean for the same varieties grown at Castle Danger was 47 mg per 100 grams. The fact that the two locations had identical means in 1947 and different means in 1948 indicates that rutabaga roots do not consistently contain the same ascorbic acid concentration from year to year when grown at the same location.

The significant varieties by locations interaction indicates that the varieties behaved differently when grown at different locations. Thus, as can be seen in Table II, varieties like New Yellow Garden and Wilhelmsburger were much higher in ascorbic acid in 1948, when grown at Grand Rapids than when grown at Castle Danger, while varieties like Invicta and American Purple Top contained about the same amount of ascorbic acid when grown at either location. This suggests that some varieties are more sensitive to environment than others. In 1948, Castle Danger was a less favorable location for the majority of varieties but Invicta and American Purple Top were not greatly affected by location.

The significant variance for "sizes" (Table III) indicates that the ascorbic acid concentration in rutabaga roots tends to be associated with their weight. The mean weights of the "small" and "large" roots and their mean ascorbic acid contents were:

	Mean Weight	Ascorbic Acid Content
	(Grams)	(Mg/100 Gms)
"Small" roots	640	57.2
"Large" roots	928	54.6
L.S.D. 5 per cent level		2.1

Thus, on the average, small roots tend to contain slightly more ascorbic acid per unit of weight than large roots. The difference is too small, however, to be of any importance either in selecting varieties for growing or in selecting roots for the table.

Cooking Tests

In order to determine the loss in ascorbic acid from rutabaga roots in cooking, single roots of five varieties grown at Castle Danger in 1947 were used. One-half of each root was analyzed for ascorbic acid uncooked and the other half was boiled in a minimum quantity of water until tender and then analyzed for ascorbic acid. The results of this test are given in Table IV. On the basis of these limited tests, it appears that rutabagas lose approximately 50 per cent of their ascorbic acid in cooking. No attempt was made to determine if the ascorbic acid was actually lost or merely transferred to the water in which the root was cooked.

Discussion

The ascorbic acid content of rutabagas varies widely from variety to variety and is also affected by environmental factors as indicated by the effects of locations and years (Table II). Bernstein, *et al* (2) found that differences in environment markedly affected the vitamin

C content of turnip greens but the particular environmental factors which were responsible were not determined. In their studies, fertilizer treatments under outdoor conditions had little effect, although variations in nutrient supply to turnips grown in sand culture had marked effect on vitamin C content. Smith and Walker (7), studying the relation of various factors to ascorbic acid in cabbage, found seasonal variations in ascorbic acid content of cabbages which had no simple relation to temperature, day length, or light energy. They also failed to find any correlation between maturity of the cabbage head and ascorbic acid content, or between soil fertility and yield and ascorbic acid content.

TABLE IV—ASCORBIC ACID CONTENT OF 100-GRAM SAMPLES OF UNCOOKED AND COOKED ROOTS OF FIVE RUTABAGA VARIETIES

Variety	Fresh (Mg)	Boiled (Mg)	Ascorbic Acid Lost (Per Cent)
Lord Derby	62.5	30 3	51 5
American Purple Top	60.0	26.7	55.5
F Special XXX	42 7	22 9	46.3
Superlative	36 6	16 7	54.3
Danish Giant	36 0	21.2	41.1
		Mean per cent loss =	49.8

In the present study no attempt was made to determine the relation of environmental factors to ascorbic acid content. The results of this study indicate that locations and years do play an important part in determining the ascorbic acid content of rutabaga roots and that these factors may not affect all varieties to the same degree. Thus, it is difficult to predict accurately the performance of a variety in terms of its ascorbic acid content, without extensive and careful testing. However, the data given in Table II indicate that, in general, the relative order of the varieties remains fairly constant from one test to another. Thus, varieties such as New Yellow Garden, Wilhelmsburger, Invicta, American Purple Top, and Jumbo are consistently higher in ascorbic acid than such varieties as Monarch, F Special XXX, Sutton's Purple Top, Danish Giant, and Golden Table Turnip.

SUMMARY

1. The ascorbic acid content of roots of 25 varieties of rutabagas grown at two locations in each of two years was determined. The data ranged from a high of 66 milligrams per 100 gram sample in New Yellow Garden to a low of 40 milligrams per 100 grams in Golden Table Turnip.

2. Ascorbic acid content of rutabaga roots was found to vary with locations and with years. Some varieties were fairly constant in ascorbic acid content regardless of location where grown while others varied widely from one location to another.

3. Small roots were found to contain slightly higher concentrations of ascorbic acid than large roots.

4. A limited number of cooking tests indicate that rutabaga roots lose approximately 50 per cent of their ascorbic acid content in the cooking process.

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Effect of DDT and Wetting Agent on Plant Growth of Triumph and Peerless Varieties of Bush Lima Beans

By R. E. Wester and C. A. Weigel, *Plant Industry Station, Beltsville, Md.*

There is little information available on the tolerance of lima bean plants to DDT when applied at concentrations used for insect control. During the summer of 1947 the authors (1) showed that a spray of wettable DDT containing 0.075 per cent of technical DDT (0.625 pounds per 100 gallons) mixed with rotenone and applied at the rate of 2.8 pounds technical DDT per acre severely injured the plants of Triumph bush lima bean (U.S. 343). This spray mixture stunted the plants and significantly reduced the yield of fresh marketable prime pods by 79 per cent. Triumph was the only one of the 14 varieties that was injured and dwarfed. Sprays prepared from wettable DDT powder from six different sources mixed with rotenone and applied at the total rate of 2.0 pounds technical DDT per acre caused a very significant reduction in fresh plant weight of the variety Triumph in comparison with rotenone spray alone as a check treatment. However no significant difference in fresh-plant weight of Peerless (a sister-line of the Triumph variety) resulted from these treatments.

These results suggested that the variety Triumph was very susceptible to injury by DDT or that possibly the wetting agent in the wettable DDT powder may have contributed to the injury. In 1948, therefore, an experiment was conducted at the Plant Industry Station, Beltsville, Maryland, to determine whether the DDT or the wetting agent was responsible, also whether applications of DDT sprays would be more injurious than DDT dusts.

The following five suspension sprays and three dusts were tested:

1. DDT-rotenone spray from wettable DDT powder.
2. DDT spray from plain DDT powder plus a wetting agent.
3. DDT-rotenone spray from plain DDT powder but with no wetting agent.
4. Rotenone spray without a wetting agent.
5. Rotenone spray with a wetting agent.
6. DDT-rotenone dust prepared from wettable DDT powder.
7. DDT-rotenone dust prepared from plain DDT powder with no wetting agent.
8. Rotenone dust alone.

The content of technical DDT was 0.075 per cent in all DDT sprays and 3 per cent in all DDT dusts. The content of rotenone was 0.01 per cent in all rotenone sprays and 0.5 per cent in all dusts.

The wettable DDT powder was a commercial product containing 51.8 per cent of DDT, whereas the plain DDT powder used in the sprays was a commercial product containing 50 per cent of DDT. Cube root powder containing 5.37 per cent rotenone was used to make the finished sprays. A commercial dust containing 0.74 per cent of rotenone was used in preparing the dust mixtures. The rotenone was used to

control the Mexican bean beetle. DDT was used to control leaf hoppers.

The commercial wetting agent used contained decylbenzene sodium sulfonate and was added to provide 0.1 per cent in the finished spray.

The arrangement of the spray test consisted of five blocks in each of which the five spray treatments were randomized. The three dust treatments were also randomized but placed to the leeward side and end of the sprayed blocks to minimize the drift of the dust over the spray-treated plots. With this planting arrangement it was possible to analyze the data by analysis of variance.

These tests were made only on Triumph, formerly tested as U.S. 343, and a sister-line variety, Peerless. The planting was done on July 16, 1948, in a clay loam soil. One row of Triumph was paired with a row of Peerless for each treatment in each plot. Each single row consisted of 35 hills spaced 1 foot apart with the rows 3.25 feet apart. Three seeds were planted in each hill and after the seedlings appeared above ground they were thinned to one plant per hill. This gave an almost perfect stand.

Applications of dusts and sprays were made on August 9, 18, 26, and September 13. Separate 3-gallon compressed-air sprayers were used for the DDT sprays and those containing no DDT. Also separate hand dusters (both rotary and bellows type) were employed for applying the dust mixtures. Applications were made in the morning on days of slight air movements soon after the leaves dried from the morning dew.

The total quantity of finished spray for the season ranged from 206 to 222 gallons per acre for each of the different treatments. The plots sprayed with DDT received an average of 1.32 pounds of technical DDT per acre for the season.

The total quantity of the two finished 3 per cent DDT dust mixtures averaged 44 and 43 pounds per acre for the season, which made the quantity of technical DDT per acre equal that on the spray plots. There were very few Mexican bean beetles and leaf hoppers on plants in each treatment.

The third day after the first application 1.16 inches of rain fell, a total 2 inches during the 3 days after the second application, only .31 inches on the fourth day after the third application, and none after the fourth application, although 1.25 inches occurred within 6 days prior to the last application. A total of 4.72 inches fell during the period of the experiment. During the growing period there was considerable dew on the foliage of the plants on the majority of mornings.

Effect on Plant Growth and Nature of Injury

By August 23, after the plants had received two applications, injury began to show on the DDT-sprayed plants of Triumph on all plots, but not on Peerless. The nature of the injury was virtually the same as occurred in the 1947 tests. The tops of all DDT-treated plants were pale green or yellowish green in color in contrast to the very dark green color of the lower leaves and of all the leaves of rotenone-treated plots. The internodes on DDT-treated Triumph plants failed to elongate normally; this gave the variety a dwarfed, prostrate appearance. Many

young leaves had a mosaic-like appearance. Later the stunting effect on Triumph was in marked contrast to the normal upright growth of the variety Peerless. This condition was maintained until the conclusion of the experiment as is shown in Figs. 1 and 2.

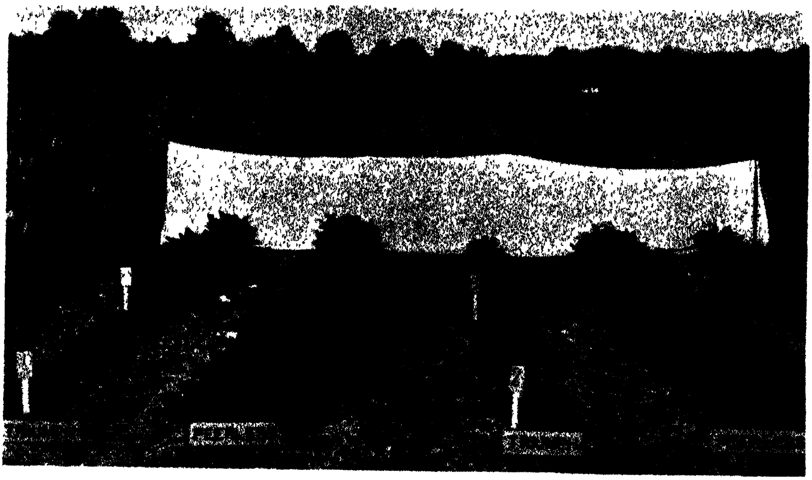

FIG. 1 Field view showing how spray 1, 2, and 3, containing DDT caused stunting and dwarfing of Triumph but did not affect Peerless. Spray treatment No 4 containing only rotenone dwarfed neither Triumph nor Peerless.

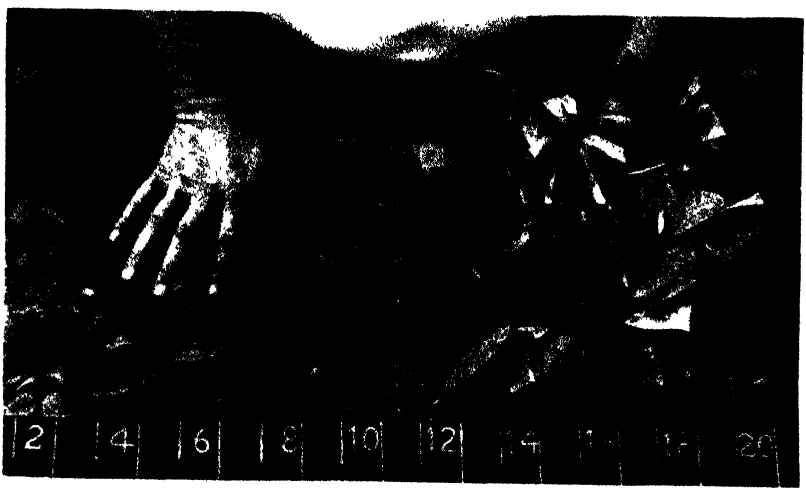

FIG. 2. 66-day-old plants of Triumph. Stunted and dwarfed plant on left sprayed with treatment No. 1 contaning wettable DDT and rotenone; normal plant to right sprayed with treatment No. 4 containing only rotenone.

Effect on Fresh Plant Weight

Since the experiment was started rather late there was not enough time for the pods to reach full maturity before the occurrence of a killing frost. The experiment was therefore terminated September 29 on which date 20 plants from the middle of each row of each variety were pulled from each plot and the fresh plant weight, including the pods, was taken immediately. This left a border of seven to eight plants at both ends of each treatment in each replicate. The data for the five replicates of each treatment of each variety were averaged and are presented in Table I.

TABLE I—Average Fresh Weight of Plants Per Plot of Triumph and Peerless Varieties of Bush Lima Beans Receiving Four Applications of the Various Insecticide Treatments

Treatment	Variety: Triumph (Grams)	Variety: Peerless (Grams)
Sprays		
1 Wettable DDT with rotenone	1,114	4,926
2. Plain DDT with wetting agent	896	4,227
3. Plain DDT with rotenone	1,824	4,496
4. Rotenone only (Check)	3,121	4,475
5. Rotenone with wetting agent	3,185	4,315
Difference required for significance between varieties: 592 grams at 5 per cent point; 808 grams at 1 per cent point.		
Difference required for significance between treatments: 547 grams at 5 per cent point; 754 grams at 1 per cent point.		
Dusts		
6. Wettable DDT with rotenone	1,429	3,551
7 Plain DDT with rotenone	1,628	3,463
8. Rotenone only (Check)	3,150	3,759
Difference required for significance between varieties: 390 grams at 5 per cent point, 537 grams at 1 per cent point.		
Difference required for significance between treatments: 487 grams at 5 per cent point; 708 grams at 1 per cent point.		

Peerless, which grows more rapidly than Triumph, was not affected by the DDT and showed a greater average plant weight on the check as well as the treated plots. DDT, with or without a wetting agent in spray formulations (treatments 1, 2, and 3), caused significant reduction in plant weight of Triumph, in comparison with treatments Nos. 4 and 5, which contained no DDT but carried rotenone alone or with a wetting agent. Spray No. 1, made from a DDT wettable powder with rotenone added, caused a significant reduction in plant weight as compared to spray No. 3 made from plain DDT that lacked the wetting agent. The known wetting agent that was added to spray No. 2 appeared to have also caused a significant reduction in plant weight. Spray No. 2, however, was the only spray that did not contain rotenone and it is possible that the lack of rotenone may have been a factor.

The unknown wetting agent in wettable DDT caused a significant reduction in average plant weight of Triumph. The known wetting agent added to the rotenone spray treatment No. 5 caused no effect on plant weight, on the basis of comparison with spray treatment No. 4 containing only rotenone (Fig. 3).

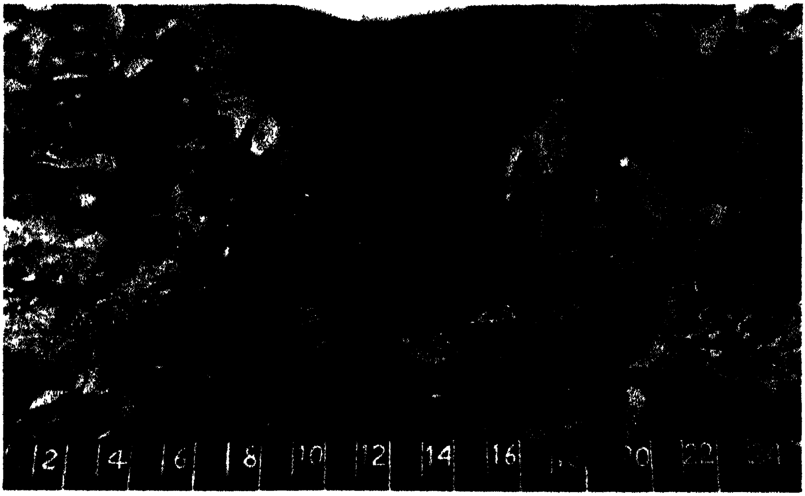

FIG. 3. 66-day-old Triumph plants not affected by wetting agent. Plant on left sprayed with treatment No. 4 containing only rotenone; plant on right sprayed with treatment No. 5 containing rotenone with wetting agent.

The DDT dust mixtures No. 6 and 7, caused a significant reduction in plant weight in comparison with treatment No. 8 containing rotenone alone. There was no apparent difference in the results from treatments Nos. 6 and 7, which indicates that the wetting agent was not injurious.

None of the spray treatments caused a highly significant difference at the 1 per cent level in plant weight of Peerless. At the 5 per cent level, however, treatment No. 1 produced significantly heavier plant weights than treatments Nos. 2 and 5.

There does not appear to be any significant difference between response to the wettable DDT plus rotenone dust and to the plain DDT plus rotenone dust.

These data show that DDT injured the variety Triumph but not Peerless. The wetting agent in the absence of DDT caused no injury, but when added to DDT, under certain conditions, it appeared to intensify the plant injury.

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Sweet Corn Fertility Studies on Newly Irrigated Lands in the Yakima Valley[1]

By W. J. Clore, *Irrigation Experiment Station,* and F. G. Viets, Jr., *U. S. Department of Agriculture, Prosser, Wash.*

Attempts to grow sweet corn on new lands have not been very successful compared with some of the older areas in the Yakima Valley where high tonnages are often produced year after year on the same land. The acreage (2) of sweet corn grown for processing in the Kittitas and Yakima valleys of Washington is approximately 7,641 acres. With considerable new land being irrigated under the Roza Project and much larger acreages to receive water in the Columbia Basin Project, investigations were initiated in 1947 to learn what factors may be involved in the production of sweet corn on virgin land.

An experiment with field corn (7) on virgin Sagemoor very fine sandy loam has shown increasing yields with the application of nitrogen up to 240 pounds per acre and no response to phosphorus. Yields and ear size were the same whether the corn was irrigated five, eight, or eleven times. The maximum yield obtained was 173 bushels of shelled corn per acre. A placement study (8) conducted during 1945 with sweet corn in the Yakima Valley gave increased yields only from additions of nitrogen. The higher yields were obtained by increase in the number of usable ears rather than by increase of ear weight.

Experiments reported by Comin and Bushnell (4), and Bushnell (3) have shown generally that the highest sweet corn yields are obtained by use of manure supplemented with chemical fertilizers containing nitrogen. Huelson and Gillis (5) report similar results when clover is plowed under with nitrogen added. Vittum (9) reported that a total application of 77½ pounds of nitrogen gave maximum yields (5.1 tons/acre) of sweet corn at Geneva, New York. Additional nitrogen failed to further increase yields or ear weight.

Experimental Procedure

Golden Cross Bantam (Crookham strain) was grown on the Roza Unit of the Irrigation Experiment Station in 1948 in an experiment involving two spacings in the row, four rates of nitrogen supply and four soil pretreatments in factorial combination.

The soil was Ritzville very fine sandy loam overlying Sagemoor and varied in depth from 3 to 5 feet to caliche. The surface soil is quite low in organic matter (approximately 1 per cent) contains 0.035 per cent total nitrogen and has a pH of 7.0 to 7.5. The virgin soil can supply 30 to 35 pounds of nitrogen per acre during the growing season.

The four pretreatments consisting of manure, check, and two winter cover crops were arranged as main plots (42⅔ feet by 80 feet) in a 4

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by 4 Latin square. The winter legumes were planted September 3, 1947. Yield of tops of the winter legumes and samples for total nitrogen analyses were taken immediately before plowing on May 17, 1948. Ten tons of steer manure were uniformly spread on the manure plots before plowing. Pertinent data on the pretreatments are summarized in Table I.

TABLE I—AVERAGE WEIGHTS AND NITROGEN CONTENTS OF MANURE AND TOPS OF WINTER LEGUMES USED IN THE PRETREATMENTS

Pretreatment	Oven Dry Weight (Tons/Acre)	Total Nitrogen	
		Per Cent	Lbs/Acre
Hairy vetch	1.34	3.61	93.7
Austrian winter peas	0.69	3.53	49.5
10 tons manure	5.80	0.86	99.8
None	0	—	—

The manure contained as much total nitrogen as did the tops of the hairy vetch, however, since the nitrogen percentage of the manure (.86 per cent) was so low little nitrogen was available.

The sweet corn was planted May 24, in rows 32 inches apart at a spacing of approximately 3 inches in the row. There were 16 rows on each pretreatment plot. Ammonium nitrate at the rates of 0, 40, 80, and 160 pounds of nitrogen per acre was side-dressed on June 18, on the four plots into which each pretreatment plot was divided at random. Thus each nitrogen plot (subplot) consisted of four rows of corn 80 feet long. When the fertilizer was applied there were pronounced differences in growth due to the pretreatments. Plants on the check and manure plots were somewhat nitrogen deficient and about 3 inches high, whereas plants on the winter legume pretreatments were dark green and about 6 inches high.

Two spacings, 6 and 9 inches in the row which gave 32,671 and 21,780 plants per acre respectively, were established at random by dividing the nitrogen plots (subplots) transversely and thinning with a hoe on June 21. The ultimate plot thus consisted of four rows 40 feet in length. The harvested area consisted of 30 feet of the two center rows of each plot.

The corn received three shallow cultivations and four irrigations after planting. Irrigation was believed to be adequate for a maximum yield.

A record was kept of silking dates, number of barren stalks, total yield and number of unhusked ears and husked usable ears. A random sample of 25 usable ears[2] was taken to obtain husk weight, kernel weight, cob weight and the amount of corn earworm damage. A commercial corn cutting machine was employed to obtain information concerning the cut whole-kernel corn.

RESULTS AND DISCUSSION

Sweet corn on the plots where vetch or peas had been grown made more rapid growth throughout the experiment than that on the check

[2] Ear not less than 4 inches long of cream-style or whole-kernel maturity.

and manured plots. Vetch produced results superior to peas in this respect. Manured plots were only a little better than the check plots.

When the corn was about 1 foot high the leaves of plants in some areas began to show an interveinal chlorosis in a spotted pattern over the field. These areas were associated with the presence of carbonates nearer the surface. This nutritional disorder may also contribute to the limited sweet corn yields obtained from new lands.

Some of the more interesting data obtained in this study are presented in Table II. Variance analyses have been made whenever the data were complete and these are summarized in Table III. Incompleteness resulted from an insufficient number of usable ears from some treatments for reliable values.

Total and Usable Ear Yield:—Both total and usable ear yields were affected to a highly significant extent by the pretreatment and by the amount of nitrogen fertilizer used. The interaction of these variables was also highly significant. Vetch plots gave the highest yields, fol-

TABLE II—RESPONSE OF GOLDEN CROSS BANTAM SWEET CORN ON NEW LAND TO WINTER COVER CROPS, MANURE AND RATES OF NITROGEN APPLICATION (AVERAGES OF FOUR REPLICATIONS OF EACH OF TWO SPACINGS)

Pretreatments	Nitrogen Applied (Lbs/Acre)	Unhusked Ear Corn		Average Husked Ear Weight (Lbs)	Per Cent Cut Corn	Per Cent Barren Stalks
		Total (Tons/Acre)	Usable (Tons/Acre)			
Check	0	0.42	0.15	0.29	—	76.9
	40	2.03	1.27	0.42	24.8	70.7
	80	3.91	2.86	0.53	31.5	45.6
	160	6.38	4.67	0.57	35.4	26.3
Average		3.18	2.25	0.45	22.9	54.9
Manure 10 tons	0	1.51	0.73	0.39	17.7	81.6
	40	2.55	1.92	0.48	35.6	49.2
	80	5.25	4.46	0.57	41.2	28.5
	160	7.96	6.80	0.62	40.6	15.5
Average		4.27	3.48	0.52	33.8	42.7
Austrian Winter Peas	0	2.00	1.40	0.43	27.2	61.1
	40	4.00	3.17	0.55	40.4	43.2
	80	5.69	4.65	0.59	38.1	29.5
	160	7.60	6.64	0.64	40.1	18.5
Average		4.82	3.96	0.55	36.5	38.1
Vetch	0	3.40	2.68	0.52	41.4	50.0
	40	6.44	5.30	0.62	41.0	25.7
	80	6.62	5.62	0.64	37.2	17.9
	160	8.40	7.15	0.65	41.0	13.7
Average		6.21	5.19	0.61	40.2	26.8
Average Response to Rates of Nitrogen Application						
	0	1.77	1.24	0.39	21.6	66.5
	40	3.75	2.92	0.52	35.4	47.2
	80	5.37	4.40	0.58	37.0	30.4
	160	7.59	6.32	0.62	39.3	18.4
Least significant difference (5 per cent level):						
Pretreatments		1.16	1.16	*	*	10.3
Nitrogen rates		0.49	0.42	*	*	4.3
Any two treatments		0.98	0.84	*	*	8.7

*Data incomplete.

TABLE III—Summary of Variances Obtained in Analysis of Sweet Corn Data

Source	Degrees of Freedom	Variances		
		Total Ears	Usable Ears	Barren Stalks
Rows	3	1,379*	1,071*	764
Columns	3	106	167	1,342*
Pretreatments (P)	3	2,721**	2,534**	4,323**
Error a	6	192	190	281
Total pretreatment plots	15			
Nitrogen rate (N)	3	10,345**	7,951**	14,005**
N × P	9	163**	131**	400**
Error b	36	50	37	73
Total nitrogen plots	63			
Spacing (S)	1	133	323*	764*
S × N	3	54	47	82
S × P	3	94	61	147
S × N × P	9	19	49	312
Error c	48	50	46	144
Total plots	127			

*F exceeds 5 per cent level
**F exceeds 1 per cent level.

lowed by peas, manure and no treatment plots in decreasing order. The response to nitrogen application was also highly significant with the maximum yields being obtained with 160 pounds of nitrogen per acre. These relationships for usable ears are shown in Fig. 1. The highest yield of usable ears, 7.15 tons per acre, was obtained with 160 pounds of nitrogen following the vetch green manure crop. This yield is above average but well below maximum yields of 10 or 12 tons per acre that have been obtained.

As a side study, rates of nitrogen fertilization were extended to include 240 and 320 pounds of nitrogen per acre on two spacings on the border area between pretreatment blocks. Greater increases in yield were obtained where 240 (6.11 tons/acre) and 320 (6.60 tons/acre) pounds as compared with 160 pounds of nitrogen per acre were used on the untreated soil. This suggests that yields in all cases were limited by insufficient nitrogen except possibly the two high rates on the untreated soil and the 160 pound rate following vetch. Plants receiving these latter treatments gave a positive diphemylamine (nitrate) test in the stalk tissue shortly before harvest.

The interaction obtained between nitrogen rate and pretreatment was due to the fact that the yields of manured plots increased proportionally greater than those of the other pretreatments as the nitrogen rate was increased. This relationship is expected when a material of wide carbon-nitrogen ratio, like the manure used here, is added to the soil.

The percentage of usable ears increased with increasing amounts of nitrogen fertilizer.

Average Ear Size:—Table II shows that the average husked ear size varied from a low of 0.29 pounds on check plots without nitrogen fertilizer to a high of 0.65 pounds on vetch plots with 160 pounds of nitrogen. Both the pretreatment and the amount of nitrogen applied

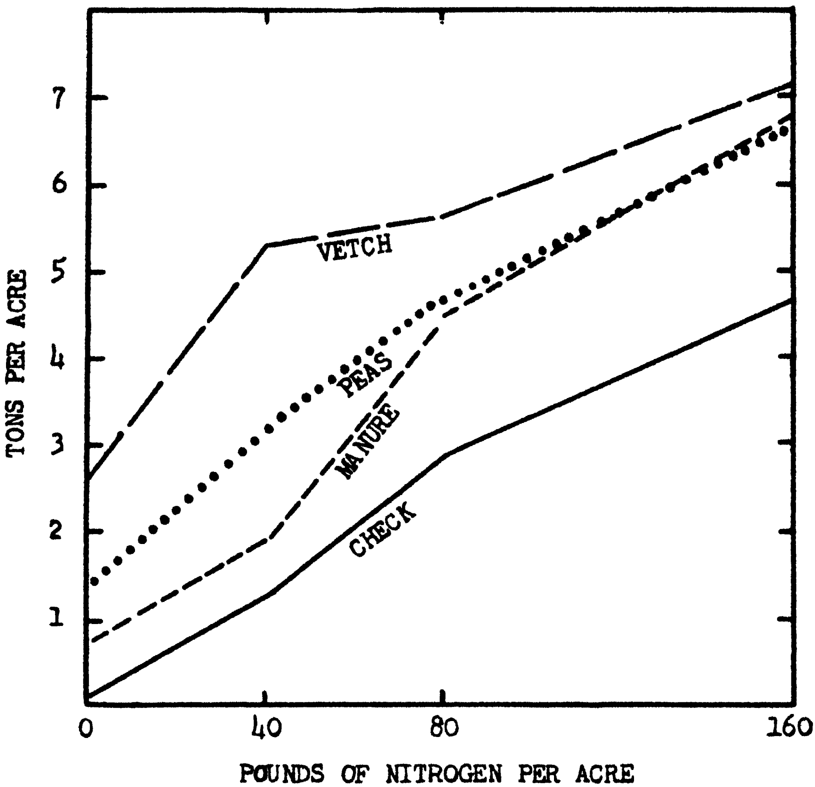

FIG. 1. The effect of side dressing nitrogen on the yields of usable unhusked sweet corn.

affected the ear size, and the relationship appears to be largely one of nitrogen supply. The amount of fertilizer applied affected ear size on the check and manure plots to a greater extent than on the pea and vetch plots.

Percentage of Cut Whole-Kernel Corn:—Based on the unhusked usable ear, pretreatments yielded the following percentages of cut, whole-kernel corn: check — 22.9 per cent; manure — 33.8 per cent; winter peas — 36.5 per cent; and vetch — 40.2 per cent. Supplemental nitrogen increased the percentage of cut corn on all treatments, except vetch, which was high over the whole range of nitrogen rates. With the exception of the check plots 40 to 80 pounds of nitrogen is sufficient in obtaining a high percentage of cut whole-kernel corn.

Percentage of Barren Stalks:—The percentage of barren stalks was decreased in the following order by pretreatments — check, manure, peas and vetch; and also decreased by increasing amounts of supplemental nitrogen. An interaction between pretreatments and nitrogen levels was found. Manure showed a higher percentage of barren stalks at low nitrogen levels and a relatively lower percentage of barren stalks

at high nitrogen levels than any other pretreatment. The relative increased value of manure at high nitrogen levels was also previously indicated by the ear yield data.

The Effect of Spacing:—Differences were found in sweet corn yields due to spacing. A rate of 21,780 plants per acre produced an average yield of usable corn for all treatments of 3.94 tons per acre while 32,671 plants per acre averaged 3.50 tons per acre. The percentage of barren stalks at the lower rate averaged 38.2 per cent and at the higher rate 43.1 per cent. Ear size between all treatments was consistently higher at the wider than the closer spacings, averaging 0.57 and 0.51 pounds per ear respectively. Spacing had no measurable affect upon the percentage of cut corn.

An interaction between spacing and fertility levels on barrenness may be expected but none was found. The lack of interaction between these variables in this study is an indication that the level of fertility is not the only variable affecting barrenness and that aerial factors are probably also operating. In this respect Bailey (1) concluded that soil or climatic conditions, or both, were vastly more important in influencing the yields per acre than spacings varying from 4 to 16 inches at 2 inch intervals in the row.

Corn Earworm Damage:—The percentage earworm damage (6) was significantly lower at high levels of nitrogen supply. Infestation was 100 per cent on the unfertilized check plots as compared with 80.8 per cent on the vetch plots with 160 pounds of added nitrogen. The amount of feeding injury was also lower. The check plots with 40 pounds of added nitrogen had a 9.1 per cent trim, whereas the vetch plots with 160 pounds of nitrogen had 4.1 per cent trim.

SUMMARY

Results are presented of a one year fertility study on sweet corn involving the use of manure, winter legumes, various nitrogen application rates, and plant spacings on virgin land.

The highest yield (7.15 tons/acre) of usable sweet corn was obtained by plowing under a vetch cover crop supplemented with 160 pounds of nitrogen. This yield, although well above average, falls short of the maximum yields of 10 and 12 tons per acre obtained on the older lands in this region. An interveinal chlorosis of leaves found on some soil areas in these studies may contribute to this difference.

Planting winter legumes was found to be much superior to the use of manure or to no treatment in sweet corn production. Corn yields, average ear weight, per cent cut whole-kernel corn, and percentage stalks with ears were all generally higher following vetch than peas.

The 10-ton manure application improved yields, but the benefit was less than that from the good crop of peas or vetch. Manure was relatively better at high rates of nitrogen application than at low rates.

Sweet corn yields were increased considerably by the application of commercial nitrogen up to the maximum applications.

The good cover crop of vetch maintained a high average ear weight with or without additional nitrogen fertilizer.

The percentage of cut whole-kernel corn was increased in all pretreatments with additions of nitrogen except in the case of vetch where it was high regardless of the amount of nitrogen used.

The percentage of barren stalks was reduced with each increment of nitrogen applied. This reduction of barren stalks was greater at the higher levels of nitrogen than at the lower levels for the 10-ton manure application.

Regardless of the pretreatment or amount of nitrogen applied, yields and size of usable ears were generally higher from 21,780 than from 32,671 plants per acre. The greater spacing also resulted in a lower percentage of barren stalks than the closer spacing.

High levels of nitrogen significantly reduced corn earworm infestation and feeding injury to the sweet corn ear as compared to low nitrogen levels.

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Growth Rates and Chemical Composition of Fruits of Four Varieties of Summer Squash

By O. A. LORENZ, *University of California, Davis, Calif.*

COMPARATIVELY little information is available regarding the rate of growth and chemical composition of fruits of the different varieties of summer squash, *Cucurbita Pepo*. Such information would be of value to growers in determining the frequency of harvests and to nutritionists desiring to know the relationship of maturity to quality and food value of the different varieties.

Cordner and Matthews (2) studied changes in the carbohydrate content of the White Bush Scallop variety during the first 11 days of growth. They found a slight reduction in the dry matter content of the older fruits. Reducing substances and total sugars showed an increase for the first few days of growth, while no definite changes were detected in sucrose, acid hydrolyzable substances, and starch. Culpepper (3) studied growth and chemical changes in the White Patty Pan (also called White Bush Scallop) and Golden Crookneck varieties grown for a total of 40 days. Reducing and total sugars showed increases up to the 9-day stage and then decreased as the fruits became older. Non-reducing sugars were fairly constant during the first 12 days of growth. Acid hydrolyzable polysaccharides were lowest in the early and late stages of development and highest when the plants were about 21 days old. Golden Crookneck averaged about 1 per cent higher in dry matter than White Patty Pan.

METHODS

The varieties studied were Early Prolific Straightneck, White Bush Scallop, Black Zucchini, and Early Summer Straightneck. Seeds were obtained from the Ferry-Morse Seed Company, San Francisco. Fruits grown at Davis, California on Yolo fine sandy loam soil were sampled first on the day of full bloom and then on each of the following 10 days. This included the period when the squash fruits would have been considered as commercially usable. Sampling was begun on July 28, 1944. Sufficient fruits with open blossoms were tagged on that date to supply material for subsequent samplings. After the fourth day of sampling not more than two tagged fruits were allowed to remain per vine. All other fruits except those tagged for sampling were picked off daily as they attained a size suitable for market. The weather was about two degrees cooler than normal for that season of the year. Maximum day temperatures averaged approximately 90 degrees F and night minimums approximately 60 degrees F.

Twenty or more fruits of each variety were collected at 9:00 a m each day. Several times this number were collected for the first 3 days of sampling in order to have sufficient material for analysis. After collection, fruits of each lot were cut into small pieces and thoroughly mixed. Duplicate 100-gram samples were taken for dry weight determinations. Similar samples were killed in boiling 80 per cent alcohol and preserved for chemical analyses. Determinations were made for

total solids, alcohol insoluble solids, acid hydrolyzable polysaccharides, insoluble solids, reducing sugars, fructose, and sucrose.

Alcohol insoluble solids were designated as that fraction insoluble in boiling 80 per cent alcohol. Total solids were estimated by adding the values for alcohol-soluble and alcohol-insoluble materials. This constituent was determined in this way because values for total solids obtained by drying 100-gram samples of the fresh materials in a forced-draft oven at 70 degrees C for 48 hours gave values which were obviously low. Reducing sugars were determined by the Quisumbing-Thomas (1) method, while sucrose was inverted with Wallenstein's invertase scales at 30 degrees C for 18 hours, after which the samples were analyzed as for reducing sugars. Starch was determined by hydrolyzing a finely ground portion of the alcohol-insoluble material for 6 hours in boiling 10 per cent HCI. All data are expressed on the fresh-weight basis.

Results

Growth rates of fruits of the different varieties are presented graphically in Fig. 1. Photographs of fruits selected for the respective weight

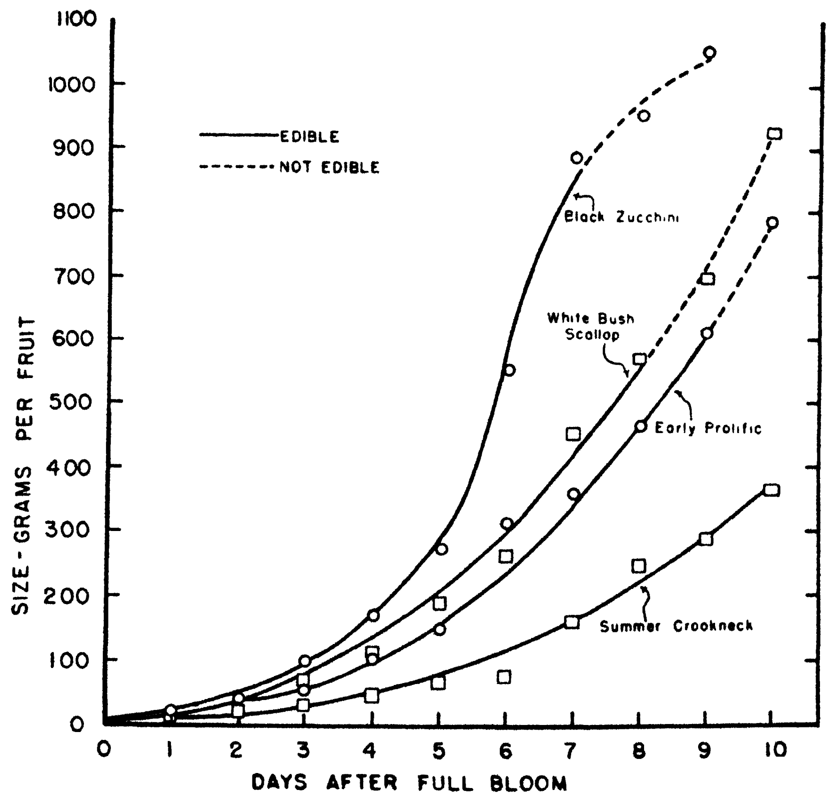

Fig. 1. Average growth rate of fruits of four varieties of summer squash.

categories shown in this graph are given in Fig. 2. Black Zucchini had the fastest growth rate, followed in order by White Bush Scallop, Early Prolific, and Summer Crookneck. Fruits of 100 grams are about the minimum in the commercial harvest of any of the varieties. Zucchini fruits reached this size on the third day after blooming while White Bush Scallop and Early Prolific attained this size on the fourth day. Summer Crookneck fruits did not attain this size until the sixth day. After the fourth day there was a very rapid rise in the growth rate of Zucchini.

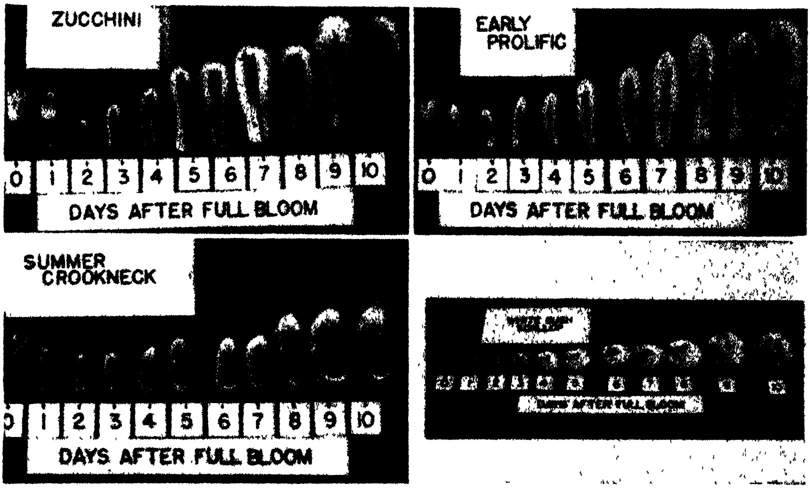

FIG. 2. Photographs of fruits representing the weight categories of fruits of the varieties shown in the graph in Fig. 1. Fruits of White Bush Scallop are reduced to approximately one-half of the magnification of the other varieties.

In California it is customary to harvest the fruits early and usually before a size of 300 grams is attained. If fruits weighing between 100 and 300 grams are considered as being acceptable for market then this allows a maximum of 2 days between harvests for the Zucchini variety, about 3 days each for White Bush Scallop and Early Prolific and approximately 4 days for Summer Crookneck.

The dotted portion of the growth curves of Fig. 1 indicate the stage of growth when the fruits would not have been acceptable for table use. At these stages of growth the flesh had become stringy and watery and the seeds enlarged and hardened. By these standards fruits of the Zucchini variety were inedible 7 days after full bloom, as compared to 8 days for Bush Scallop and 9 days for Early Prolific and over 10 days for Summer Crookneck.

Certain chemical changes occurring during the growth of the fruits of the four varieties are given in Fig. 3. Alcohol-insoluble solids and reducing sugars made up the greater portion of the dry matter of

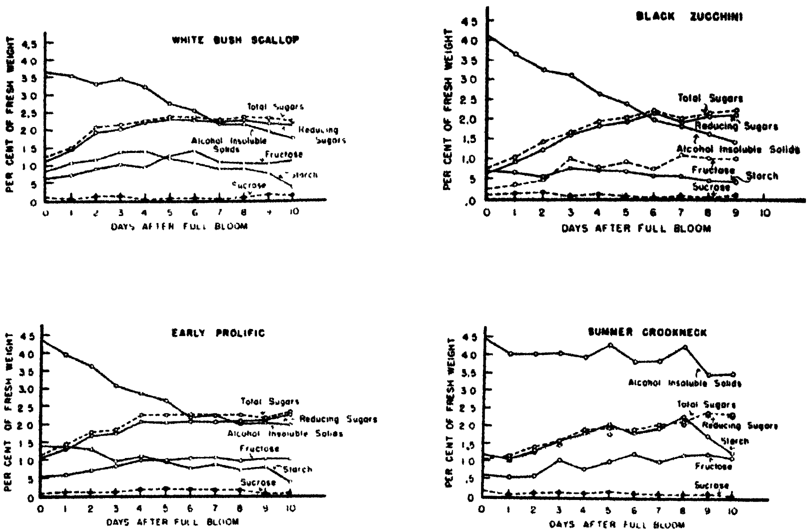

FIG. 3. Relationship of maturity to the partial chemical composition of fruits of four varieties of summer squash.

fruits of all varieties. Fructose accounted for approximately one-half of the reducing sugars.

Black Zucchini:—In the Zucchini variety there was a gradual decrease in alcohol-insoluble solids from over 4 per cent on the date of blooming to about 1.5 per cent in the 9-day fruits. Reducing sugars increased from less than 1 per cent to over 2 per cent in 9 days, with the greatest increase occurring during the first 6 days after bloom. Starch was fairly constant during the 9-day growth period, remaining slightly over .5 per cent. Sucrose was very low during the entire growth period.

Early Prolific:—Alcohol-insoluble solids in fruits of this variety decreased about half during the first 6 days and then remained almost constant. Starch was at a maximum in full bloom fruits and decreased gradually until the tenth day at which time it was approximately half of the original content. Reducing sugars increased markedly for the first 4 days after the fruit set and then remained fairly constant for the next 6 days.

White Bush Scallop:—Most chemical changes occurring in fruits of this variety closely paralleled those of Early Prolific. The main difference was that starch increased up to about the fourth day after anthesis and then decreased for the next 6 days. This is at variance with the data of Cordner and Matthews (2) which showed no consistent changes in starch content.

Summer Crookneck:—In fruits of this variety alcohol-insoluble solids were higher initially than in the other varieties and showed only a very slight decrease throughout the 10-day growth period. Reducing

sugars and fructose showed a gradual increase and were about twice as high in 10-day fruits as in those just blooming. The values obtained for both reducing and total sugars were somewhat lower than those reported by Culpepper (3) for this variety while the other carbohydrate fractions closely approximated the values he reported.

The data in Fig. 4 give the trends for some of the major constituents comparing the four varieties.

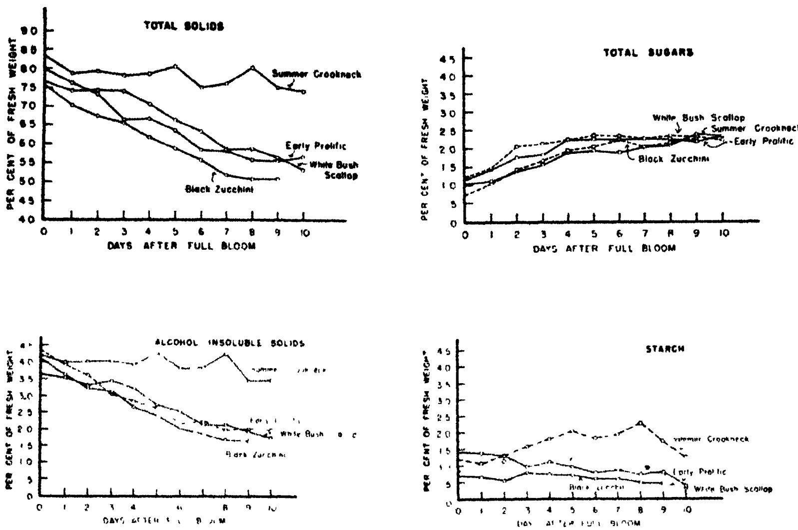

FIG. 4. Relationship of maturity to the partial chemical composition of fruits of four varieties of summer squash.

Total Solids:—At full bloom fruits of all of the varieties had a total solids content of approximately 8 per cent, with Summer Crookneck in the top position. During the 10-day growth period, total solids decreased slowly to about 7.5 per cent in Summer Crookneck. In the other varieties the decrease in solids was regular and of much greater magnitude. Ten days after blooming, fruits of the Early Prolific and White Bush Scallop contained about 5.5 per cent total solids while Zucchini contained only 5 per cent. When prime fruits are considered (3 to 6 days after bloom), those of Summer Crookneck was the highest in total solids followed in order by Bush Scallop, Early Prolific, and Zucchini.

Alcohol-Insoluble Solids:—Alcohol-insoluble solids followed the same general trends in the various varieties as did total solids. They accounted for about one-half of the total solids. In the Summer Crookneck variety alcohol-insoluble solids showed only a slight decrease with maturity of the fruit but in the other varieties they decreased fairly gradually during the 10-day period to about one-half of the original content.

Starch:—Starch generally accounted for slightly over one-third of

the alcohol-insoluble solids. In the Summer Crookneck variety it increased for about the first eight days and then decreased. In the other varieties there was a tendency for starch to remain constant for the first few days and then to decrease. When the fruits were in the best edible state, those of Summer Crookneck were the highest in starch followed in order by Bush Scallop, Early Prolific, and Black Zucchini.

Total Sugars:—All varieties were similar in sugar content and reducing sugars were dominant. There was a marked increase in sugar during the 4 days after bloom and then a gradual leveling off for the next 6 days. During the period of prime edibility fruit of White Bush Scallop had the highest sugar content and Summer Crookneck and Zucchini the lowest.

Summary

The growth rates and chemical composition of fruits of four varieties of summer squash were determined at full bloom and then on each of the following 10 days. Black Zucchini had the fastest rate of growth followed in order by White Bush Scallop, Early Prolific, and Summer Crookneck. Black Zucchini fruits reached a stage large enough for commercial harvest on the third day after bloom, as compared to about 4 days for White Bush Scallop and Early Prolific and 6 days for Summer Crookneck.

The chemical composition of fruits of all varieties was markedly similar, the exception being that fruits of Summer Crookneck were higher in total solids, alcohol-insoluble solids, and starch than the other varieties. Alcohol-insoluble solids constituted about one-half of the total solids. Reducing sugars accounted for practically all of the sugars as sucrose was very low. Fructose made up about one-half of all of the reducing sugars.

Taking the Early Prolific variety as an example, fruits on the fifth day after bloom, when they would have been considered as of prime market condition, had slightly over 6 per cent total solids, nearly 3 per cent alcohol-insoluble solids, slightly over 2 per cent reducing sugars, about 1 per cent fructose, and about .2 per cent sucrose.

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Observations on Flowering and Fertility in Some Varieties of Jersey and Moist-flesh Sweetpotatoes[1]

By H. E. WARMKE and H. J. CRUZADO, *Federal Experiment Station, Mayaguez, Puerto Rico*[2]

THE breeding of sweetpotatoes *(Ipomea Batatas* (L.) Lam.) is comparatively new. Before 1924, work consisted in scattered reports of collection of open-pollinated seeds and the beginnings of seedling testing (Stout, 10, 11). In 1925 Thompson (13) published a bulletin summarizing his work with some 1800 seedlings (open-pollinated) which he produced and grew in the Virgin Islands. In 1926 Stout (12) reported the production of seeds from controlled cross-pollinations from plants grown in the greenhouse at the New York Botanical Garden. The next year Chung (4) produced 321 seeds from reciprocal crosses in the Hawaiian Islands. Tioutine (14) reported making nearly 14,000 controlled crosses, from which a large number of hybrid seedlings were obtained and the foundations laid for a scientific sweetpotato breeding program. He reported highly successful methods of hybridization and the production of three different interspecific hybrids. Miller (8, 9) published studies in 1937 and 1939 on methods of inducing flowering and seed production in Louisiana. These methods have been used widely in subsequent breeding investigations.

In his early work, Stout (10) clearly understood the problem and pointed out that sexual reproduction in sweetpotatoes is limited in two ways: (a) by the non-blooming habit, and (b) by the low fertility of blossoms, once formed. The sweetpotato, being in all probability a native of the American Tropics, is adapted to a warm climate and a long growing period. Though being able to grow and yield commercial crops of roots in more northern climates, it flowers best under tropical or sub-tropical conditions. There is considerable difference in disposition to flower among the different varieties, but many of them flower sparsely, or not at all, in the continental United States.

The ease with which sweetpotatoes reproduce vegetatively and the fact that they have been propagated largely by this method, at least since the coming of the white man to America, may also have contributed to the low fertility. Asexual reproduction allows the accumulation of recessive gene mutations, which may be more or less detrimental to the sexual process. Moreover, asexual propagation of new varieties which may have arisen by somatic mutation makes such varieties clonal. If the original mutant had a tendency toward self-incompatibility, asexual propagation extends this incompatibility past the individual and to the entire variety.

The cytological investigations of King and Bamford (6), indicating that the cultivated varieties are probably hexaploids with approximately 90 chromosomes in somatic cells, also help contribute to an understanding of the high sterility in the species. Although these

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[1]Cooperative project with the Division of Vegetable Crops and Diseases of the BPISAE and Southern Sweetpotato Breeders.

[2]Administered by the Office of Experiment Stations, Agricultural Research Administration, U. S. Department of Agriculture.

workers did not report studies on meiosis in *Ipomea Batatas,* it is probable that chromosomal non-disjunction and other irregularities are common. The high percentage of poorly formed pollen grains in the commercial varieties strongly suggests that cytological abnormalities contribute to reduced fertility.

The Jersey-type varieties have been particularly difficult to induce to reproduce sexually, chiefly because of the non-flowering habit in the continental United States. Pool reports never having seen flowers on the Jersey varieties (Stout 12, pp. 130). Hartman (5) reported complete failure of flower induction in Vineland Bush, several strains of the Big Stem Jersey subgroup, and in Little Stem Jersey varieties, after a very thorough series of investigations extending over a period of 8 years. Borthwick (3) likewise reported failure in flower induction and seed production with Orange Little Stem and Big Stem Jersey grown in nutrient solutions, after varying photoperiod, light intensity, temperature, and attempting girdling and grafting. Mikell, Miller, and Edmond (7) reported the production of six flowers on Maryland Golden in Louisiana, but failure of seed formation. Other instances of limited flowering in Jersey varieties have occurred in Oklahoma and Virginia (personal conversation with H. B. Cordner and F. T. McLean).

Under sub-tropical conditions the Jersey varieties are less refractory. Bailey (1, 2) reported flowering in Big Stem Jersey, Vineland Bush, and Yellow Jersey in Puerto Rico and obtained seeds from controlled cross-pollinations with the first two of these. Warmke and Cruzado (15), also working in Puerto Rico, recently reported flowering in the variety Orange Little Stem and successful crosses between this variety and four moist-flesh varieties. It is the purpose of the present paper to report further results in flowering and fertility—particularly in crosses between Jersey and moist-flesh varieties.

Materials and Methods

Roots of the various continental varieties were secured from Dr. C. E. Steinbauer of the Division of Vegetable Crops and Diseases, BPISAE, and from Dr. Julian C. Miller of Louisiana State University. Native varieties were collected at different localities on the Island.

Roots were bedded and sprouts were transplanted when they had reached sufficient size. One group of sprouts was set in the field in July 1947 and another group in June 1948. All plants were trained up on 6-foot chicken wire trellises and were thinned from time to time by removing excess leaves and vines, following the methods of Miller (9). Commercial fertilizer was added and plants were sprayed periodically with wettable sulphur and DDT to control attacks of a red spider, probably Tetranychus sp.; agromyzed flies, Agromyza spp., which attack the flowers; and a stem borer, *Sylepta elevata* (F.).

Blossoms were emasculated between 8 a.m. and 11 a.m. of the day prior to anthesis (before shedding of pollen) by removing the entire corolla and adhering stamens, or by cutting the corolla tube at its midpoint with a specially constructed scissors and removing the exposed anthers with forceps. Emasculated flowers, as well as intact

flowers to be used as a source of pollen, were covered with short lengths of soda straws or with small glassine bags to prevent entrance of insects. Pollinations were made between 7 a.m. and 9 a.m. the day following emasculation by applying pollen from one or more anthers of the desired male parent to the stigma of the desired female parent by means of a sterile forceps. The stigmas were then re-covered for protection against insect contamination.

Results

Flowering:—Three Jersey varieties (Orange Little Stem, Maryland Golden, and Yellow Jersey) and 17 moist-flesh varieties (P.I.–153907, P.I.–153909, P.I.–153655, B–5903, B–5928, B–5966, B–5988, L–5, L–12, L–78, Heartgold (L–138), Queen Mary, U.P.R.–3, Mameya, Don Juan, Toro Negro Wild, and Unit I Puerto Rico) were brought to flower in field plots at Mayaguez this past season. Only three varieties (Red Jersey, Big Stem Jersey, and Vineland Bush), of a total of 23, failed to produce flowers. The latter three varieties were only 4 months of age at the onset of the flowering season and had made poor growth. Big Stem Jersey and Vineland Bush have previously been brought to flower at this station, by Bailey, and it is hoped that older plants of these varieties may be brought to flower during the coming season. It was found that the group of plants which had been in the field over a year flowered more profusely than the younger plants. Flowering has been abundant in most of the moist-flesh varieties and in Orange Little Stem, but somewhat sparce in Yellow Jersey and Maryland Golden.

Hybridization:—Over 2,200 controlled crosses were made during the season, most of them between moist-flesh and Jersey varieties. From these crosses 227 fruits containing 337 seeds were obtained, for a over-all seed-set of 15.26 per cent. The individual crosses made, as well as the number of fruits and seeds set, are given in Table I. The relative fertilities of the individuals used, both as male and as female parent, are given in Tables II and III.

Although a scarcity of blossoms limited the number of crosses that could be made with Yellow Jersey and Maryland Golden, it would appear that these varieties are quite highly fertile—perhaps more fertile than Orange Little Stem. The Jersey varieties, as a whole, set 11.21 seeds per 100 crosses when used as the female parent and 7.26 seeds per 100 crosses when used as the male parent.

Among the moist-flesh varieties, P.I. 153907 and P.I. 153909 proved to be exceptionally fertile as females, with percentages of seed set of 30.38 and 21.97, respectively. The native varieties, Mameya and Toro Negro Wild, were highly fertile as male parents, with seed sets of 36.58 per cent and 42.86 per cent, respectively. No seeds were obtained from a very limited number of crosses with the varieties Heartgold, Queen Mary, and UPR–3. The moist-flesh varieties, as a group, set 15.46 seeds per 100 crosses when used as a female and 29.99 seeds per 100 crosses when used as a male.

As indicated in the tables, 116 of the 337 hybrid seeds produced

TABLE I—RESULTS OF SWEETPOTATO CROSSES (MAYAGUEZ, PUERTO RICO, WINTER, 1948–49)

Parents	No. Crosses Made	No. Fruits Set	No. Seeds Set	Per Cent Seeds Set
Yellow Jersey × P.I -153909				
Total	4	0	0	0.00
Maryland Golden × P.I.-153909				
Total	3	1	2	66.67
Orange Little Stem × P I.-153655	51	7	8	15.69
Orange Little Stem × P.I.-153907	8	0	0	0.00
Orange Little Stem × P.I.-153909	28	1	1	3.57
Orange Little Stem × B-5928	7	0	0	0.00
Orange Little Stem × Unit I P.R.	2	1	1	50.00
Orange Little Stem × Mameya	4	0	0	0.00
Total	100	9	10	10.00
P I.-153655 × Yellow Jersey	17	3	5	29 41
P.I.-153655 × Maryland Golden	4	0	0	0.00
P.I.-153655 × Orange Little Stem	715	14	18	2.52
P.I.-153655 × B-5928	9	0	0	0.00
P.I.-153655 × Toro Negro Wild	5	0	0	0.00
P I -153655 × P.I -153909	3	0	0	0.00
P.I.-153655 × Mameya	282	42	92	32.62
Total	1,035	59	115	11 11
P I.-153907 × Yellow Jersey	5	1	2	40.00
P.I.-153907 × Maryland Golden	3	2	4	133 33
P.I -153907 × Orange Little Stem	241	27	31	12.86
P.I -153907 × B-5928	2	0	0	0 00
P.I.-153907 × B-5988	1	0	0	0 00
P I -153907 × Toro Negro Wild	3	1	3	100 00
P.I.-153907 × Mameya	84	38	63	75 00
Total	339	69	103	30.38
P.I.-153909 × Yellow Jersey	5	4	4	80 00
P.I -153909 × Maryland Golden	1	1	1	100.00
P.I.-153909 × Orange Little Stem	249	28	32	12.85
P.I.-153909 × B-5928	2	0	0	0.00
P.I.-153909 × Toro Negro Wild	2	0	0	0.00
P.I.-153909 × Mameya	87	28	39	44.83
Total	346	61	76	21.97
B-5928 × Orange Little Stem	44	1	1	2.27
B-5928 × P.I.-153655	2	0	0	0.00
B-5928 × Mameya	6	1	1	16 67
Total	52	2	2	3.85
B-5988 × Orange Little Stem	49	4	4	8.16
B-5988 × B-5928	13	0	0	0.00
B-5988 × Mameya	1	0	0	0.00
Total	63	4	4	6.35
Queen Mary × Orange Little Stem	13	0	0	0 00
Queen Mary × B-5928	1	0	0	0 00
Queen Mary × Mameya	3	0	0	0.00
Total	27	0	0	0 00
Heartgold × Orange Little Stem	8	0	0	0.00
Heartgold × B-5928	10	0	0	0.00
Total	18	0	0	0.00
Unit I P.R. × Orange Little Stem				
Total	1	0	0	0.00
UPR-3 × Orange Little Stem	5	0	0	0.00
UPR-3 × B-5928	3	0	0	0.00
Total	8	0	0	0.00
Toro Negro Wild × Orange Little Stem	32	1	1	3.13
Toro Negro Wild × P.I -153655	4	1	1	25.00
Toro Negro Wild × Mameya	118	17	19	16.10
Total	154	19	21	13.64
Mameya × Orange Little Stem	40	1	1	2.50
Mameya × B-5928	15	0	0	0.00
Mameya × Toro Negro Wild	4	2	3	75.00
Total	59	3	4	6.78
Grand Totals	2,209	227	337	15.26

TABLE II—RELATIVE CROSS FERTILITY OF INDIVIDUAL JERSEY SWEET-POTATO VARIETIES (SEASON 1948–49, MAYAGUEZ, PUERTO RICO)

	Number Crosses Made	Number Fruits Set	Per Cent Fruits Set	Number Seeds Set	Per Cent Seeds Set
Yellow Jersey					
As female	4	0	0.00	0	0.00
As male	27	8	29.63	11	40.74
Maryland Golden					
As female	3	1	33.33	2	66.67
As male	8	3	37.50	5	62.50
Orange Little Stem					
As female	100	9	9.00	10	10.00
As male	1,397	76	5.44	88	6.30
Totals as female	107	10	9.35	12	11.21
Totals as male	1,432	87	6.08	104	7.26

TABLE III—RELATIVE CROSS FERTILITY OF INDIVIDUAL MOIST-FLESH SWEETPOTATOES VARIETIES (SEASON 1948–49, MAYAGUEZ, PUERTO RICO)

	Number Crosses Made	Number Fruits Set	Per Cent Fruits Set	Number Seeds Set	Per Cent Seeds Set
P.I. 153655					
As female	1,035	59	5.70	115	11.11
As male	57	8	14.04	9	15.79
P.I. 153907					
As female	339	69	20.35	103	30.38
As male	8	0	0 00	0	0.00
P.I. 153909					
As female	346	61	17 63	76	21.97
As male	38	2	5 26	3	7.89
B-5928					
As female	52	2	3.85	2	3.85
As male	72	0	0.00	0	0 00
B-5988					
As female	63	4	6.35	4	6.35
As male	1	0	0.00	0	00.0
Mameya					
As female	59	3	5.08	4	6.78
As male	585	126	21.54	214	36.58
Toro Negro Wild					
As female	154	19	12.34	21	13.64
As male	14	3	21.43	6	42.86
Heartgold					
As female	18	0	0.00	0	0.00
As male	0	0	0.00	0	0.00
Queen Mary					
As female	27	0	0.00	0	0.00
As male	0	0	0.00	0	0.00
UPR-3					
As female	8	0	0.00	0	0.00
As male	0	0	0.00	0	0.00
Unit I P.R.					
As female	1	0	0.00	0	0.00
As male	2	1	50.00	1	50.00
Totals as female	2,102	217	10 32	325	15.46
Totals as male	777	140	18.02	233	29.99

were from crosses between Jersey and moist-flesh varieties. In 104 of these crosses the Jersey variety was used as the male parent and in 12 it was used as the female parent. Seeds from all crosses involving Jersey varieties have been sent to the Division of Vegetable Crops and Diseases, BPISAE, for germination, testing, and distribution.

Data on relation of fertility to date of crossing are given in Table IV. In general, setting is poor at both ends of the season (October-November and the end of March) and high during the middle (January 16 to February 15). During the first 15 days of February, the high average of 41.20 seeds were obtained for each 100 crosses made.

TABLE IV—RELATION OF FERTILITY TO DATE OF CROSSING IN SWEETPOTATOES (SEASON 1948–49, MAYAGUEZ, PUERTO RICO)

	Number Crosses Made	Number Fruits Set	Per Cent Fruits Set	Number Seeds Set	Per Cent Seeds Set
Oct 16 to 31	10	0	0.0	0	0 0
Nov 1 to 15	98	3	3.06	3	3.06
Nov 16 to 30	264	0	0.0	0	0.0
Dec 1 to 15*	299	30	10 03	47	15.72
Dec 16 to 31	405	39	9.63	47	11 60
Jan 1 to 15	266	15	5 64	21	7 89
Jan 16 to 31	312	50	16 03	81	25.96
Feb 1 to 15	250	66	26.40	103	41 20
Feb 16 to 28	84	7	8 33	8	9 52
Mar 1 to 15	198	17	8 59	27	13 64
Mar 16 to 31	23	0	0 0	0	0 0
Totals	2,209	227	10 28	337	15 26

*After December 1, crossing was begun at about 7 00 a. m. each day.

Discussion and Conclusions

At least five of the difficult-to-flower Jersey varieties, Orange Little Stem, Yellow Jersey, Maryland Golden, Big Stem Jersey, and Vineland Bush, have successfully been brought to flower in field plantings in Puerto Rico (Bailey 1, 2 and the present report). The plants were trellised and thinned, but no other special treatments were used. Among these varieties, flowering has been abundant only in Orange Little Stem, but a sufficient number of flowers for crossing has been obtained from the other varieties.

It would thus appear that the Jersey varieties can be brought to flower and to reproduce sexually, and that they differ from other sweetpotato varieties only in being somewhat more exact in their environmental requirements for flowering. What these particular requirements are was not determined in these studies, but it would appear that they are satisfied by the sub-tropical conditions found in Puerto Rico.

It was the primary purpose of the present studies to induce simultaneous flowering in various Jersey and moist-flesh sweetpotatoes, for the purpose of inter-crossing varieties from the two groups. The Jersey varieties set heavy crops of roots close to the plant, have spindle-shaped roots of uniform size and shape, and show considerable nematode resistance. Various moist-flesh varieties, on the other hand, have high yield, resistance to Fusarium wilt, and high carotine content.

Hybridization between the two groups should introduce new germ plasms into each and make possible many obviously advantageous combinations of characters. To the authors' knowledge, the present group of 116 hybrid seeds (the majority of them involving Jerseys and the new wilt-resistant introductions, P.I. 153655, P.I. 153907, and P.I. 153909) constitute the first sizable group of hybrids ever produced between Jersey and moist-flesh varieties. They should be sufficient to give important information as to ease and success with which characters from these two great groups of varieties may be interchanged and stabilized.

Summary

Three Jersey sweetpotato varieties (Orange Little Stem, Maryland Golden, and Yellow Jersey) and 17 moist-flesh varieties (P.I. 153655, P.I. 153907, P.I. 153909, Queen Mary, Unit I Puerto Rico, U.P.R.–3, L–5, L–12, L–78, Heartgold, B–5903, B–5928, B–5966, B–5988, Mameya, Toro Negro Wild, and Don Juan) have flowered in field plots during the past season at Mayaguez, Puerto Rico. Only Big Stem Jersey, Vineland Bush, and Red Jersey have failed to flower, and plants of these varieties were perhaps too young to be expected to flower. During the months of October through March some 2000 crosses were made, the majority between Jersey and moist-flesh varieties. From these crosses, 337 hybrid seeds were produced, 116 being from crosses between Jersey and moist-flesh varieties. The Jersey varieties, as a whole, set 11.21 seeds per 100 crosses when used as the female parent and 7.26 seeds per 100 crosses when used as the male parent. The moist-flesh varieties, as a group, set 15.46 seeds per 100 crosses when used as female and 29.99 seeds per 100 crosses when used as male. It was found that the per cent of seed set at the beginning and end of the season was low as compared with the middle of the season. During the first 15 days of February (midseason) 41.28 seeds were harvested from each 100 crosses.

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Effect of Storage on the Carotene Content of Fourteen Varieties of Sweet Potatoes

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The sweet potato is recognized as an important dietary component for humans and livestock in the United States and various parts of the world, and therefore any factors which may increase or conserve its nutritive value are worthy of further study. One of the most important nutritional contributions of this crop is its pro-vitamin A. The purpose of this report is to present data on (a) the varietal differences in beta carotene content, (b) the influence of storage at relatively high temperature (75 degrees F) on the stability of beta carotene in the sweet potato, (c) the ratio of beta carotene to the total pigment content.

MacLeod, Armstrong, Heap, and Tolbert (5) employing standard bioassay technique with the white rat, studied the effect of storage on the vitamin A content of sweet potatoes. These investigators found that Porto Rico and Yellow Jersey varieties contained three and four times as much vitamin A after storage for 2 months as at harvest. Miller and Covington (7) using the chemical method of Guilbert (3) reported that the carotene content of Porto Rico variety increased rapidly during the first month of storage, followed by a gradual increase during the second, after which time there was a trend for the amount of this pigment to remain relatively constant. Mitchell and Lease (8) using the same variety, found a decrease during storage at room temperature and a more rapid loss at a higher one. Speirs, Cochran, Peterson, Sherwood, and Weaver (11) also using Porto Rico have concluded that storage had little effect on the carotene content. However, Ezell and Willcox (2) in a detailed study of the effect of storage on the carotene content of five varieties of sweet potatoes have reported an absolute increase in this pigment during curing and storage. These investigators (1) had previously called attention to the fact that the roots of the sweet potato contained appreciable amounts of yellow pigments other than beta carotene and the carotene to total pigment ratio varied among different varieties and within varieties. These findings, if confirmed, would be of considerable significance in evaluating the pro-vitamin A content of this vegetable.

According to Matlack (6) beta carotene is the principal pigment of the sweet potato. However, he did find in addition a small quantity of violaxanthin. Other investigators including Lease (4), Villere, Heinzelman, Pominski, and Wakeham (12), Sherman and Koehn (10), and O'Connor, Heinzelman, and Jefferson (9) have confirmed the findings of Matlack (6) by quantitative investigations.

In the brief review of previous work presented here, one is impressed with differences in conclusions reached by various investigators in different sections of the country. It may be suggested that these may be due to actual biochemical and physiological differences in the living roots which may have been brought about either by different soil or

climatic conditions or both rather than actual differences in the method of storage or analysis.

Materials and Methods

All varieties used in this study were grown at the Louisiana Agricultural Experiment Station, Baton Rouge, Louisiana. The soil is the Lintonia type and 4-12-4 fertilizer was applied to the experimental plot at the rate of 400 pounds per acre. The planting date was June 15, 1948, and the roots were harvested during the last week of October. The roots were selected at random from five replications for each variety and the excess soil was removed by brushing. The cleaned roots were placed in crates and stored at 75 degrees F throughout the experiment.

Chemical analyses were made at the time of harvest and each month thereafter for a period of 4 months. Twelve roots were selected at random from each variety for this purpose. These roots were washed, dried, split lengthwise and a representative longitudinal V-shaped portion of each root was obtained by a motor driven rasp. This finely ground material from the 12 roots was thoroughly mixed before sampling. The method of carotene analysis was that of O'Connor, Heinzelman, and Jefferson (9) in which cold ethyl alcohol is used for extraction, dicalcium phosphate adsorption column for the purification, and 2,2,4–trimethylpentane (iso-octane) as the solvent in the spectrophotometric measurements. The total pigment was determined from the iso-octane extract before chromatographing, and the carotene after chromatographing. Dry matter determinations were made by placing weighed samples of this ground potato in a drying oven at 103 degrees C for 12 to 15 hours.

Results and Discussion

The results of this study are presented in Table I. It is to be noted in this table that there is considerable difference among varieties of the sweet potato as to the amount of total pigment and beta carotene

TABLE I—Effect of Storage at 75 Degrees F on Total Pigment and Beta Carotene Content of Fourteen Varieties of Sweet Potatoes

Variety	Total Pigment Mg Per 100 Gm Dry Weight					B-Carotene Mg Per 100 Gm Dry Weight					Ratio: $\frac{\text{B-Carotene}}{\text{Total Pigment}} \times 100$				
	No. Days After Harvest					No. Days After Harvest					No. Days After Harvest				
	0	30	60	90	120	0	30	60	90	120	0	30	60	90	120
Unit I Porto Rico	22.0	21.7	20.3	20.2	22.7	21.4	20.8	20.0	19.9	21.0	97	96	99	99	93
Queen Mary	33.0	35.1	28.4	31.9	25.6	31.6	35.1	27.0	30.8	24.0	96	100	95	97	94
Ranger	22.8	29.5	28.4	31.9	25.6	21.8	28.6	27.0	30.8	24.0	96	97	95	97	94
Heartogold (L-138)	26.6	33.6	31.9	34.2	30.9	24.5	34.7	31.9	35.3	29.8	92	103	100	103	96
L-9	30.8	29.9	26.8	29.3	26.3	29.8	29.9	26.5	29.6	25.0	97	100	99	101	95
L-78	28.7	31.2	27.4	27.4	25.3	27.8	31.8	26.3	28.0	25.0	97	102	96	102	97
L-156	32.5	34.4	28.2	32.4	22.8	32.8	35.4	28.6	31.7	22.0	101	103	99	98	93
L-184	15.4	17.1	14.2	14.5	14.9	13.7	16.0	13.4	14.5	14.1	89	94	94	100	95
L-224	34.0	39.4	32.4	32.3	29.6	34.8	41.3	32.7	32.8	28.0	102	105	101	102	95
L-225	15.5	19.9	17.5	16.9	14.7	15.2	19.9	17.2	16.4	14.2	98	100	98	97	97
L-228	33.1	38.0	30.8	29.4	22.3	34.0	31.8	29.2	29.7	21.8	103	91	95	101	98
L-240	23.9	23.3	22.8	25.8	22.2	23.0	25.0	20.5	25.8	22.0	92	107	90	100	99
L-241	46.5	47.5	42.1	—	41.7	49.1	51.5	41.4	—	40.0	106	108	98	—	96
L-244	31.5	36.1	30.9	21.2	27.9	27.9	37.9	30.3	30.9	26.0	89	108	98	99	93

present. Of the 14 varieties analyzed in this work L–184 and L–225 have the lowest concentration of total pigment and beta carotene at harvest and L–241 the highest. It is of interest that 4 months after this time the same relationship is maintained. Furthermore, some varieties such as Unit I Porto Rico, L–240 and L–184 show relatively little change in total pigment and beta carotene during storage, whereas varieties such as L–156 and L–228 are characterized by a more pronounced change. There is a significant increase in both total pigment and beta carotene during the 30 days following harvest when one determines the significance of the difference between the means using the "t" test. However, there are individual varieties such as Unit I Porto Rico which actually show a slight decrease during this period. The greatest increase was in Heartogold and this variety and Ranger both contained more total pigment and beta carotene at the end of 4 months' storage than was present at harvest. The data presented in Table I indicate a small but significant decrease in both the total pigment and beta carotene at the end of 4 months' storage at 75 degrees F as compared to the mean at the time of harvest. However, this relative stability of the pro-vitamin A in the sweet potato during storage is an important consideration.

The most significant finding in this investigation is the constantly high ratio of carotene to total pigment in the sweet potato. The average ratio of the 14 varieties at harvest was 97, after 30 days 101, after 60 days 97, after 90 days 100, and after 120 days 96. These findings differ considerably from the results of Ezell and Willcox (1) who reported that this ratio ranged from 28 in the case of Triumph to 88 for Maryland Golden. They found a ratio of 81 for Porto Rico whereas the results presented in Table I for Unit I Porto Rico indicate a value of 97. No explanation is available for these findings unless it is the actual difference in the chemical composition of the roots grown in different regions. The results in Table I indicate that practically all of the pigment in the 14 varieties studied is beta carotene. However, it is not to be interpreted that all of this pigment would be biologically available for animals or humans as there are various factors influencing the utilization of the pro-vitamin A in the sweet potato.

Conclusions

The results of this investigation show that there is a wide range in the beta carotene content of the roots of different varieties of sweet potatoes. An increase was observed in the beta carotene content of some varieties during the first month of storage at 75 degrees F and a decrease after 4 months' storage. Furthermore, it was found from the ratio of carotene to other pigment in the root of the sweet potato that the principal pigment is beta carotene. This confirms the earlier finding of Matlack (6).

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Studies of Total Soluble Solids and Sugar Content in Sweet Potatoes

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Until Miller (2,3) induced flowering and seed setting in the sweet potato, improvement by breeding was limited to clonal selection. As a result of Miller's work, the sexual method is now chiefly used in the development of superior varieties. At the Louisiana station, a large number of seedlings are grown and evaluated each year. Since the evaluation of such characters as sugar, starch and carotene content by standard chemical methods is costly and time consuming, the development of short, reliable methods would be decidedly advantageous. Studies were undertaken to determine whether the refractometer can be used to get an estimate of sugar content in sweet potatoes. Since 10 varieties and 4 segments of the storage period were used, additional information was obtained on varietal and storage period differences in dry weight, total soluble solids, sugar content, and shrinkage.

Materials and Methods

Unit I Porto Rico, Ranger, White Star and seedlings L–37, L–64, L–138, L–155, L–224, L–227, and L–241 were used. Of these 10 lots L–37, L–138, L–155, L–241, and Ranger were relatively high in moisture, Unit I Porto Rico, L–64, L–224, and L–227 were moderately high and White Star was low in moisture.

The plants were grown in Lintonia silt loam soil of the University Experiment Station farm and the roots were harvested on October 20, 1947. For any given variety or seedling, 60 roots of the U. S. No. 1 grade were selected and divided into five comparable lots, each consisting of 12 roots. One lot was prepared for immediate analysis and the remaining four lots were placed in a room for curing. The temperature, humidity and number of days in storage for each lot are shown in Table I.

TABLE I—Temperature, Humidity and Days of Each Storage Period (1947)

Temperature and Humidity	Storage Period									
	Oct 20		Oct 20 to Oct 27		Oct 20 to Nov 3		Oct 20 to Nov 17		Oct 20 to Dec 3	
	C*	S†	C	S	C	S	C	S	C	S
Temperature	—	—	78-82	—	78–82	—	78-82	70 74	78-82	68 72
Humidity	—	—	78-82	—	78-82	—	78 82	70 76	78-82	60 65
Days	0	0	7	0	14	0	14	14	14	30

*C = curing. †S = storage.

For any given date, the roots were washed, dried and sampled. Sampling was done by cutting longitudinal sections from each half of the roots by means of power driven sugar beet sampling rasp. The rasped material was collected in glass jars and sampled for dry weight, total soluble solids and total sugars. Dry weight determinations were

made by drying 10 grams of the rasped material for 24 hours in an oven maintained at 95 degrees C. Total soluble solids were determined by means of a Zeiss field refractometer. The liquid of 10 grams of rasped tissue was squeezed through cheese cloth; allowed to set from 3 to 5 minutes on a watch glass; and transferred to the refractometer for reading. Total sugars were determined by using the Munson-Walker Method (1).

Discussion of Results

Varietal and Seedling Differences:—The data, presented in Table II, show both significant and insignificant varietal and seedling differences in dry weight, total soluble solids, sugar content and shrinkage. For example, White Star had by far the highest dry weight and the lowest sugar content; Unit I Porto Rico had a significantly higher total soluble solids than Ranger, L–37, White Star and L–227, statistically the same total soluble solids as L–64, L–138, and L–241 and actually the same total soluble solids as L–224; and Unit I Porto Rico lost significantly less weight in storage than Ranger, L–37, L–138, L–155, and L–224. Thus in sweet potato breeding programs varieties and seedlings can be obtained which differ significantly in dry weight, total soluble solids, sugar content and shrinkage.

The data, presented in Table II, also show both significant and insignificant differences between the various curing and storage periods. For example, there was a sharp and highly significant increase in relative dry weight during the first 7 days of curing and a practically constant moisture content during the remaining periods; a marked and highly significant increase in total soluble solids during the first 7 days of curing and a gradual increase during the entire curing period and a

TABLE II—Varietal and Seedling Means of Dry Weight, Total Soluble Solids, Sugar Content, and Shrinkage of Varieties and Seedlings of Sweet Potatoes

Variety or Seedling	Dry Weight (Per Cent)	Total Soluble Solids (Per Cent)	Sugar Content (Per Cent)	Loss of Weight in Storage (Per Cent)
White Star	40.85	12.44	3.21	5.01
L–227	32.22	11.30	4.46	5.30
L–224	32.20	13.08	4.17	5.74
Unit I Porto Rico	31.90	13.08	4.40	5.02
L–64	30.16	13.00	4.44	5.54
L–37	28.92	11.84	4.44	5.90
L–155	28.22	12.48	4.30	6.64
L–138	27.33	12.76	5.06	6.09
Ranger	27.32	11.78	4.13	6.36
L–241	26.95	12.88	4.60	5.56
Difference required for significance—				
5 per cent	0.62	0.62	0.58	0.65
1 per cent	0.83	0.82	0.77	0.88
Storage period	Means of the Ten Varieties and Seedlings			
At harvest	29.84	10.46	2.35	
Cured 7 days	30.80	12.57	3.80	3.79
Cured 14 days	30.99	12.76	5.11	4.95
Cured 14 days and stored 14 days	30.66	13.17	5.08	6.43
Cured 14 days and stored 30 days	30.75	13.36	5.25	7.70
Difference required for significance—				
5 per cent	0.44	0.44	0.41	0.46
1 per cent	0.60	0.59	0.55	0.62

constant sugar content during the remaining periods. Thus, on the average, sweet potato varieties and seedlings may be expected to increase in total soluble solids and sugar content during the curing period and to gradually increase or remain practically constant in these constituents during the storage period.

The Use of the Refractometer as an Estimation of Sugar Content:— The data, presented in Table III, show that practically no relation existed between total soluble solids and dry weight, and between dry weight and total sugars. On the other hand, a fairly close and highly significant positive correlation was found between total soluble solids and total sugars. The highly significant regression coefficient shows that, on the average, for every unit change in total sugars there was a 0.730 unit change in total soluble solids. Thus, total soluble solids, as determined by the Zeiss refractometer, can be used as fairly reliable guide to sugar content in sweet potatoes.

TABLE III—Correlation and Regression Coefficients of Data in Table II

Statistical Constant	Total Soluble Solids and dry Weight (Per Cent)	Total Sugars and Soluble Solids (Per Cent)	Dry Weight and Total Sugars (Per Cent)
Coefficient of correlation	0 07	0 733**	0.22
Coefficient of regression		0 730**	

**Highly significant.

Conclusions and Summary

Studies were made to determine the dry weight, total soluble solids, sugar content and shrinkage of 10 varieties and seedlings of sweet potatoes and to show the relation of total soluble solids to the sugar content of the juice.

For all periods combined, White Star, the only starch-feed type in the test, had a greater dry weight and a lower sugar content than the table stock types. There were significant and insignificant differences in dry weight, total soluble solids, sugar content and loss of weight in storage between White Star and the table stock types.

For all the varieties combined, dry weight increased during the first 7 days of curing and remained practically constant during the remaining periods; total soluble solids increased rapidly during the first 7 days of curing and increased gradually during the remaining periods; total sugars increased rapidly during the entire curing period and remained practically constant during the storage period and loss in weight was rapid during the curing period and gradual during the storage period.

No relation was found between total soluble solids and dry weight and between dry weight and total sugars. However, a close and highly significant correlation occurred between total soluble solids and total sugars.

The results show that total soluble solids, as determined in these studies, are a fairly reliable index to the sugar content of table stock types of sweet potatoes.

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Cracking and Keeping Quality of Porto Rico Sweetpotatoes as Influenced by Rate of Fertilizer, Nitrogen Ratio, Lime, and Borax

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Cracking of sweetpotatoes causes large economic losses in many parts of the South. Many theories have been advanced regarding the cause of this cracking. Some of these are: Excess of nitrogen, poor distribution of moisture, excessive use of lime, lack of minor elements, and excess of organic matter.

Willis (7) focused attention on boron as a minor element essential in the growth of sweetpotatoes and he recommended the use of small amounts of borax to prevent or reduce cracking of the fleshy roots and improve the flavor and quality of the flesh.

In order to obtain information on the influence of rate of application of fertilizers, nitrogen ratio, lime, and borax on cracking, an experiment was set up to study these factors. The sweet potatoes from the various plots were placed in storage and held 5 months, primarily to determine the influence of amount of fertilizer and nitrogen ration on the keeping quality, since questions about such effects frequently arise.

Experimental Procedure

Each of the materials was applied at three levels. The field plan was a split-plot arrangement of three randomized blocks in which the main plots were for rates of fertilizer; the first split, for three amounts of lime; the second for three nitrogen ratios, and the third for three amounts of borax. This made a total of 243 ultimate plots each year, or 729 for the 3 years. These ultimate plots consisted of four rows 25 feet long spaced 4 feet apart. Records of only the two inside rows were taken. Spacing in the rows was 15 inches.

The experiment was conducted on a different field each of the 3 years (1944, 1945, and 1946). As can be noted in Tables I to III inclusive there was a very high percentage of cracking in sweetpotatoes grown on the fields selected.

The lime and borax were applied in the row and mixed with the soil approximately 10 days before planting. The fertilizer was applied in bands on each side of the row. The bed was prepared by listing on these materials.

The 4-8-8 fertilizer was a commercial ready-mixed type. The 8-8-8 treatment consisted of a 4-8-8 application before planting and a side dressing of sodium nitrate about a month after planting to give the equivalent of an 8-8-8 formula The 0-8-8 treatment was accomplished by adding muriate of potash to a commercial 0-14-7 and using an amount of this mixture to give the equivalent 0-8-8 rate. Hydrated lime was used to secure quick action. The borax was regular agricultural borax of nearly 100 per cent purity.

The amount of fertilizer, nitrogen ratio (fertilizer grade), and

amount of lime are given in Tables I to III inclusive. Borax was applied at rates of 0, 10, and 30 pounds per acre.

The Porto Rico sweetpotato plants were planted about May 5. The experiments were located on fields of the United States Horticultural

TABLE I—TOTAL YIELD OF SWEETPOTATOES (IN BUSHELS PER ACRE) AS INFLUENCED BY RATE OF FERTILIZER APPLICATION, FERTILIZER GRADE, AND LIME (MEAN OF THREE YEARS)

Rate of Fertilizer (Pounds Per Acre)	Fertilizer Grade	Yield at Lime Application (Pounds Per Acre) Indicated					
		0	1,000	3,000	Average	Average*	Average†
200	0-8-8 4-8-8 8-8-8	218.1 238.2 215.5	232.3 216.4 253.1	206.2 203.0 250.8	218.8 219.2 239.8		
Average		223.9	233.9	220.0		225.9	
600	0-8-8 4-8-8 8-8-8	242.6 246.8 272.4	240.6 227.4 253.5	227.0 260.0 258.0	236.7 242.5 261.3		
Average		253.9	240.5	248.3		247.6	
1,000	0-8-8 4-8-8 8-8-8	225.1 242.8 271.7	237.4 257.5 271.0	223 8 215 3 226.2	228.7 238 5 256.3		
Average		246.5	255.3	221.7		241.2	
Average (all rates)	0-8-8 4 8-8 8-8-8	228.6 242.6 253.1	236.8 233 9 259.0	219.0 226.0 245.1			228 1 234.2 252.4
Average*		241.4	243.2	230.0			

*No significant difference between lime application or rate of fertilizer applications.
†Difference required for significance at 5 per cent level (between fertilizer grades): 12.0.

TABLE II—MARKETABLE YIELD OF SWEETPOTATOES (IN BUSHELS PER ACRE) AS INFLUENCED BY RATE OF FERTILIZER APPLICATION, FERTILIZER GRADE, AND LIME (MEAN OF THREE YEARS)

Rate of Fertilizer (Pounds Per Acre)	Fertilizer Grade	Yield at Lime Application (Pounds Per Acre) indicated					
		0	1,000	3,000	Average	Average*	Average†
200	0-8-8 4-8-8 8-8-8	86.0 92.9 78.1	82.7 73.6 94.7	63.1 64.0 74.4	77.3 76.8 82.4		
Average		85.7	83.6	67.2		78.8	
600	0-8-8 4-8-8 8-8-8	97.5 105.2 113.6	84.9 79.5 95.6	66.1 88.5 80.4	82.8 91.1 96.5		
Average		105.4	86.7	78.3		90 1	
1,000	0-8-8 4-8-8 8-8-8	88.2 83.5 90.3	86.5 83.2 88.2	85.9 87.4 63.8	86.8 84.7 80.7		
Average		87.3	85.9	79.0		84.1	
Average (all rates)	0-8-8 4-8-8 8-8-8	90.6 93.9 94.0	84.7 78.8 92.8	71.7 79.9 72.9			82.3 84.2 86.5
Average*		92.8	85.4	74.8			

*Difference required for significance at 5 per cent level (between lime application): 9.1.
†No significant difference between fertilizer rates or grades.

TABLE III—CRACKING OF SWEETPOTATOES AS INFLUENCED BY RATE OF FERTILIZER APPLICATION, FERTILIZER GRADE, AND LIME (MEAN OF THREE YEARS)

Rate of Fertilizer (Pounds Per Acre)	Fertilizer Grade	Per Cent Cracked at Lime Application Indicated					
		0	1,000	3,000	Average	Average†	Average‡
200	0-8-8	33.6	40.7	42 1	38.8		
	4-8-8	36 1	43.6	44.4	41.4		
	8-8-8	38.6	39.5	48.9	42.3		
Average		36.1	41.3	45 1		40.8	
600	0-8-8	38.9	38.8	42.9	40.2		
	4-8-8	34 3	38.2	43.5	38.7		
	8-8-8	41.9	40.6	46.4	43.0		
Average.		38.4	39.2	44.3		40.6	
1,000	0-8 8	33.9	35.9	36.6	35.5		
	4-8 8	42.2	47.7	41.7	43.9		
	8-8 8	49.9	49.2	56.3	51.8		
Average		42.0	44.3	44.9		43.7	
Average (all rates)	0-8-8	35.5	38.5	40.5			38.2
	4-8-8	37.5	43.2	43.2			41.3
	8-8-8	43.5	43 1	50 5			45.7
Average*		38.8	41.6	44.7			

*Difference required for significance at 5 per cent level (between lime application): 2.9.
†Difference between rates of fertilizer not significant.
‡Difference required for significance at 5 per cent level (between fertilizer grades): 1.5.

Field Station, Meridian, Mississippi, in 1944 and 1946, and on a privately owned nearby field in 1945. The soil type of the field used in 1944 was mostly Ruston fine sandy loam with some Ruston loamy sand and Red Bay fine sandy loam. In 1945 one block was planted on Ruston sand and the other two blocks on Ruston loamy sand. In 1946 the entire field was Ruston fine sandy loam. In 1944 and 1946 the sweetpotatoes followed summer and winter legume cover crops. In 1945 they followed corn. The soils were low in total nitrogen. As determined by the A.O.A.C. (1) method the nitrogen content of the plots receiving no added nitrogen was .02 to .05 per cent in samples of the upper 6 inches of soil. The pH of the soil was determined with a glass electrode and averaged 5.3 (determined by converting individual pH readings to hydrogen-ion concentration for averaging) in the upper 6 inches of soil. Addition of 1000 pounds of lime raised the pH to an average of 5.7 and the addition of 3000 pounds brought it to 6.6. These are averages for all three locations.

After the records on total yield, marketable yield, and percentage of cracking were obtained, the marketable roots (U. S. No. 1 and U. S. No. 2 grades) were placed in slatted bushel crates, cured for 10 to 14 days at 85 degrees F and high relative humidity, and stored in an electrically heated, thermostatically controlled sweetpotato storage house with the thermostat set at 50 degrees. Losses were unusually high because the roots were rather badly skinned during the extra handling involved in obtaining the field records on total and marketable yield and cracking. The decay which developed in storage was mostly Rhizopus rot.

All percentage data were obtained on a weight basis.

Results

Yields and Cracking:—Borax had no significant effect on either total yield, marketable yield, or percentage of cracking (since borax had no effect on any of the factors studied, for the sake of brevity, data on this material are not presented separately). Although cracking was severe in these experiments, none of the symptoms of boron deficiency described by Nusbaum (5) were observed; so probably boron was not a limiting factor here for sweetpotato production. Rapid tests (3) indicated about 15 ppm boron in the upper 6 inches of soil before any applications were made. Apparently cracking in these experiments was not related to boron deficiency. Nusbaum (5, 6), reporting on experiments in which borax corrected other deficiency symptoms of sweetpotatoes, found that added borax either did not reduce cracking or actually increased it.

In addition to the main experiment, some small-scale experiments in applying borax to the plant bed were run. Applications at rates as high as 1000 pounds per acre were made in the plant bed, besides dipping the seed roots in 10 per cent borax solution. Plants from these treatments were set in the field in which applications ranging from 0 to 75 pounds per acre were made. Cracking was not influenced by either plant bed or field treatments in these experiments. Sprouting and growth of the plants were inhibited by the 10 per cent dip and the 200-pound and 1000-pound bed applications, and slight burning of leaf edges was noted one year on very light sandy soil in the 30-pound and 75-pound field applications.

Rate of fertilizer application had no significant effect on total yield, marketable yield, or cracking (Tables I to III inclusive).

Lime had no significant influence on total yield of sweetpotatoes but it did have a highly significant effect on marketable yield and cracking. With increasing lime applications there was a decrease in marketable yield and an increase in percentage of cracking (Tables I to III inclusive).

As is apparent in Table II nitrogen did not have a significant influence on the yield of marketable sweetpotatoes, but there was a highly significant increase in percentage of cracking (Table III) with increased nitrogen. Total yield (Table I) was significantly higher with the 8-8-8 than either the 0-8-8 or 4-8-8 fertilizer grades. Nusbaum (6) also found that high nitrogen resulted in more severe growth cracking.

The interactions fertilizer ratio by fertilizer rate and fertilizer grade by lime were both highly significant for cracking. It is evident in Table III that use of fertlizer of 8-8-8 grade resulted in a very marked increase in cracking at the 1000-pound fertilizer application and at the 3000-pound lime application.

Storage Behavior:—The keeping quality of sweetpotatoes was not influenced either by rate of fertilizer application (Tables IV and V) or by borax.

Lime significantly increased decay (Table IV) but did not have any effect on weight loss in storage (Table V).

TABLE IV—DECAY OF SWEETPOTATOES IN STORAGE AS INFLUENCED BY RATE OF FERTILIZER APPLICATION, FERTILIZER GRADE, AND LIME (MEAN OF THREE YEARS)

Rate of Fertilizer (Pounds Per Acre)	Fertilizer Grade	Per Cent Decay in Storage at Lime Application Indicated					
		0	1,000	3,000	Average	Average†	Averag
200	0-8-8	6.3	9.3	10.7	8.8		
	4-8-8	10.0	8.2	14.0	10.7		
	8-8-8	9.9	11.6	12.9	11.5		
Average		8.6	9.7	12.5		10.3	
600	0-8-8	10.9	10.3	10.8	10.7		
	4-8-8	8.9	10.5	5.9	8.4		
	8-8-8	8.6	10.2	10.0	9.6		
Average		9.5	10.3	8.9		9.6	
1,000	0-8-8	6.6	4.7	8.9	6.7		
	4-8-8	5.6	13.3	12.6	10.5		
	8-8-8	11.5	12.3	24.4	16.1		
Average		7.9	10.1	15.3		11.1	
Average (all rates)	0-8-8	7.9	8.1	10.1			8.7
	4-8-8	8.2	10.7	10.8			9.9
	8-8-8	10.0	11.4	15.8			12.4
Average*		8.7	10.1	12.2			

*Difference required for significance at 5 per cent level (between lime applications): 2.8.
†Differences between fertilizer rate not significant.
‡Difference required for significance at 5 per cent level (between fertilizer grades): 2.0.

TABLE V—WEIGHT LOSS OF SWEETPOTATOES IN STORAGE AS INFLUENCED BY RATE OF FERTILIZER APPLICATION, FERTILIZER GRADE, AND LIME (MEAN OF THREE YEARS)

Rate of Fertilizer (Pounds Per Acre)	Fertilizer Grade	Per Cent Weight Loss in Storage at Lime application Indicated					
		0	1,000	3,000	Average	Average*	Average†
200	0-8-8	12.8	12.7	14.4	13.3		
	4-8-8	13.6	13.3	14.8	13.9		
	8-8-8	13.7	14.1	15.7	14.5		
Average		13.4	13.4	15.0		13.9	
	0-8-8	13.1	13.4	14.3	13.6		
600	4-8-8	14.3	12.6	11.7	12.9		
	8-8-8	12.7	15.6	14.5	14.3		
Average		13.4	13.9	13.5		13.6	
1,000	0-8-8	11.0	11.5	11.4	11.3		
	4-8-8	13.0	15.6	13.4	14.0		
	8-8-8	13.9	14.0	14.2	14.0		
Average		12.6	13.7	13.0		13.1	
Average (all rates)	0-8-8	12.3	12.5	13.4			12.7
	4-8-8	13.6	13.8	13.3			13.6
	8-8-8	13.4	14.6	14.8			14.3
Average*		13.1	13.6	13.8			

*No significant difference between lime or rate of fertilizer applications.
†Difference required for significance at 5 per cent level (between fertilizer grades): 0.4.

Both decay and weight loss were greater with increased nitrogen ratio (Tables IV and V).

The interaction fertilizer grade by fertilizer rate was highly significant for decay and significant for weight loss in storage, and the inter-

action fertilizer grade by lime was highly significant for weight loss. As is apparent in Table IV, the 8-8-8 fertilizer produced an especially high amount of decay at the 1000-pound level. In Table V it can be noted that weight loss with the high nitrogen ratio was highest with the 1000-pound and 3000-pound lime applications. The lowest weight loss was at the 1000-pound rate of fertilizer with the 0-8-8 grade.

These results should not deter a grower from using nitrogen in his sweetpotato fertilizer if it will increase his yield. In the experiments reported herein, nitrogen in the fertilizer was not essential for sweetpotato production as it did not significantly influence marketable yield (although it did slightly increase total yield and cracking). This is a possible explanation for the difference in these results and those reported by Erwin (2) in Iowa, who found that sweetpotatoes from plots receiving nitrogen rotted less than did those from the no-nitrogen plots. In Erwin's experiments, nitrogen was apparently necessary to secure good yields. Morgan (4) also working in Iowa, found that sweetpotatoes from plots receiving complete fertilizer yielded substantially better and kept better in storage than did those from plots receiving no fertilizer.

Since lime and nitrogen ratio were the only treatments that increased cracking significantly and since these same treatments also increased decay, it is possible that the factors that induce cracking of sweetpotatoes also make them more susceptible to decay.

Summary

Neither rate of borax application nor rate of fertilizer had any significant effect on cracking or keeping quality of sweetpotatoes in storage. High nitrogen did increase the yield but also increased cracking, so that the marketable yield was not influenced. Lime increased cracking and decreased marketable yield. Both lime and nitrogen had a slightly adverse effect on keeping quality in storage.

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Row-Crop Fungicide Concentrate Application[1]

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LACK OF light-weight equipment capable of adequately applying pesticides to row crops is often a limiting factor in their production. This is particularly true under wet soil and climatic conditions conducive to inoculum dissemination and development of epidemic diseases. Experimentation for 2 years has yielded progress; first, with a garden tractor-mounted air-blast machine and second, with a field tractor-mounted mist-blower attachment[2]. The prime concern has been gaining information on the requisite principles involved, but mechanical improvements have of necessity resulted. Concurrently, fungicidal concentrates have been formulated to replace conventional large-volume aqueous sprays and thus further to eliminate weight.

EQUIPMENT DEVELOPMENT

In general, experiments with mist-blower equipment have yielded gross data on insect and disease control not adapted to approved statistical analysis. Machines have lacked precision and the experimental design of treatments was unsuitable for quantitative testing particularly with fungicides. Row crops offered a good medium for obtaining data and in 1947 a Bolens Huski HiBoy garden tractor was equipped with a "mist blower" (Fig. 1, A). Initially, two fixed nozzles for treating

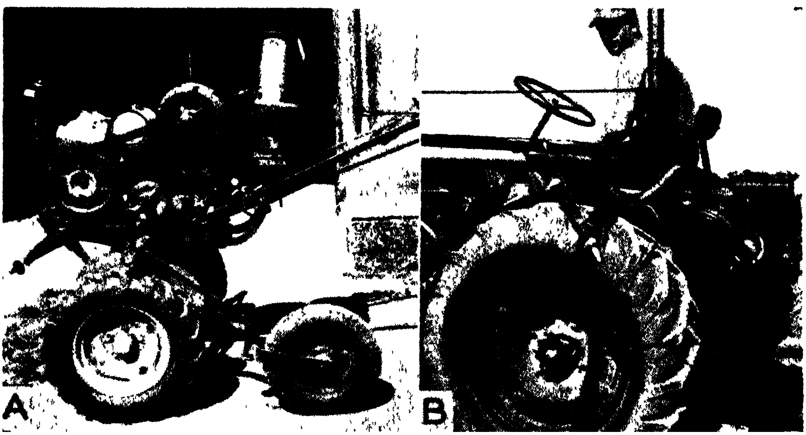

FIG. 1. A, "Mist blower" mounted on Bolens garden tractor as used for 1947 experiments. Note the door knob air-blast deflector.
B, Tractor-mounted Bean "Portomist" air-blast attachment used in 1948.

[1]Contribution No. 739 of the Rhode Island Agricultural Experiment Station.
[2]The cooperation of the John Bean Mfg. Co. by supplying equipment, and the assistance of Dr. S. F. Potts and Mr. R. V. Spencer in design are gratefully acknowledged.

a single row were provided, but soon a single fixed nozzle, pointing forward and downward into the row, was found more satisfactory.

Three mechanical factors became apparent as important contributors toward the degree of injury resulting from application of a given fungicide-in-oil formulation. These were the angle of the spray cone, the proximity of the nozzle to the foliage, and the size of the liquid droplet. In initial trial on potatoes, severe injury was noted in a narrow band at the nozzle level on the foliage. Further trials, with the machine stationary and discharging the equivalent of 10 gallons of oil per acre, showed that with the nozzle 2 feet from the potato plant, mild injury was produced; at 3 feet severe injury resulted where the spray cones of the two nozzles converged; but at 4 feet, where turbulence occurred, little or no injury resulted.

The nozzle air-blast velocity of about 85 miles per hour required the plants to be more than 3 feet away to avoid damage. A target of wrapping paper held 3 feet from a nozzle for a 2-second exposure to the spray cone demonstrated a distribution pattern only 6 inches in diameter. It was evident that either the angle of the spray cone must be widened or the mist be deflected uniformly. An oval deflector (porcelain door knob) was placed ½ inch in front of the nozzle and a uniform coverage pattern 3 feet in diameter was produced on a target 3 feet away. Apparently, the wider the angle of the spray cone, the closer the nozzle may be to the sprayed surface without producing injury, assuming that the oil droplet size is uniform. Although the deflector brought about two necessary improvements, that is, widening of the angle of the spray cone and turbulence of the mist-laden air, mechanically it appeared desirable to attain these characteristics by other means in future nozzles.

The 1947 experiments, applying mists with the above equipment to field plots of potato, tomato, cucumber, and bean plants showed the potentialities and limitations of this method. A garden tractor-mounted mist blower can be engineered to cover adequately vegetables, such as beet, celery or bean with a pesticide, but mechanical injury due to a 22-inch height of clearance is too great on mature melon, tomato or potato plants. Epidemic diseases, such as potato late blight, cucumber downy mildew, and bean anthracnose were checked by dosages of 3 to 5 gallons per acre containing as low as 0.4 pound of organic copper fungicide. Paraffinic-type oils low in aromatic fraction were less injurious than naphthenic types when used as carriers for the fungicide. Droplet size and distribution pattern were of greater importance than phytotoxic differences between two such oils. In general, foliage injury increased as volatility decreased. This may result from the degree of volatilization of the droplets in transit permitting a smaller deposit on the foliage. Also, the deposited droplet would remain liquid on the leaf surface for a shorter period of time and, hence, be less likely to penetrate. Furthermore, fungicides dissolved in oil appeared much more injurious than the oil alone, presumably because the oil readily carried a phytotoxic dose of the fungicide through the protective barrier of cutin. The "oil-blotting" capacity of the plant surface must be considered in applying oil formulations of toxicants.

For the 1948 trials, a Bean-Cooley "Portomist" skid-mounted air-blast machine was bolted as a removable attachment to a Case VI tractor (Fig. 1, B). This unit had attached a demountable 4-row boom equipped with four air nozzles 3 feet apart over which were mounted four Fitzhenry-Guptill VS-67 atomizing nozzles that discharged the concentrates as a flat fan onto the air blast. Originally, the air nozzles had a round orifice, but this produced a narrow air stream which gave poor distribution of the toxicant. Four fish-tail air nozzles with directional fins were substituted to overcome this deficiency in the machine, and were used the major part of the season. The height and nozzle direction of the entire boom were adjustable to the growth of the potato (Fig. 2) and bean plants. The air blast was directed downwards at a 45 degree angle toward the rear of the tractor.

FIG. 2. Row-crop pesticide concentrate applicator in use on potatoes. The adjustable boom for directing the air blast is shown.

A qualitative measure of the deposit produced by this machine was obtained by exposing slides in fixed positions representing various plane surfaces on stakes in the potato row. The slides were assayed in the laboratory by standard spore germination procedure with *Stemphylium sarcinaeforme*. The data indicate that good to fair coverage was obtained on calm days. However, on windy days good coverage was obtained on only those slides at which the nozzles were directed, and most of the remaining surfaces had little or no deposit. As wind movement increases, greater air-blast velocity and volume are necessary to deposit sufficient fungicide especially on under leaf surfaces.

REQUIREMENTS OF EQUIPMENT

Data from the two seasons indicate that the air-blast must fulfill four requirements: (a) volume sufficient to replace air in the plant

zone; (b) velocity sufficient to agitate and expose all leaf surfaces to the "mist"; (c) velocity sufficient to be unaffected by surface winds; and (d) volume and velocity must not be of such magnitude as to injure succulent tissue at close range. The application of pesticide-in-oil concentrates to row crops without injury necessitates droplet micronization. The largest droplets than can safely be applied would probably have to be less than 30 microns in diameter. None of the tested methods for producing mists have completely fulfilled this requirement. The shearing action of the air blast in the Potts-Spencer nozzles used in 1947 was insufficient to overcome the surface tension forces of the liquids in order to produce droplets within the non-injurious size range. The 1948 machine provided droplet micronization by low pressure, low-volume nozzles. Although this type of nozzle produced a major percentage of fine droplets (2 to 10 microns) the mist contained too many droplets up to 300 microns in diameter. Therefore, a formulation of Procop 110 dissolved in oil and emulsified in water was tested on the theory that the division of the fungicide-in-oil droplets within the water would spread over a larger area when deposited on the leaf, and thus eliminate the factor of oil penetration and its resultant injury. This treatment was obviously so superior to the fungicide-in-oil alone, that all fungicides having adequate oil solubility were converted to water emulsions. Such formulations have two advantages over aqueous concentrates: (a) under conditions of low humidity, droplets of the latter evaporate so rapidly that poor coverage is obtained; and (b) the fungicide-in-oil emulsion formulations provide non-volatile bulk to the droplet which limits the degree of shrinkage and insures the plant surfaces being reached by a liquid droplet. Furthermore, after the water evaporates, the deposit of fungicide-in-oil which remains has excellent weathering properties. In fact, the solvent action of the oil on the lipide and wax constituents of the cutin may incorporate the fungicides into the leaf's epidermal surface. Fungicide-in-oil emulsions are less limited by droplet size and are more practical than other formulations with the type of equipment tested. However, the coarser droplets and the vaporization of water in transit will require perhaps 10 gallons of spray per acre for adequate coverage rather than 5 gallons in oil alone.

Weeding Corn With Chemicals[1]

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SOON after the selective herbicidal properties of 2,4–D were discovered many investigators directed their efforts in studying its possibilities for controlling weeds in corn. To date a tremendous amount of information has been published dealing with rates and methods of application, effects of different 2,4–D formulations, varietal response, weather and soil conditions, and so on. This work has progressed to a point where 2,4–D is now being used to weed thousands of acres of corn in the United States particularly in post emergence applications. As might be expected the response from treatments is not always comparable and much more work is necessary before foolproof recommendations can be made.

In 1945 a study was begun at this station to ascertain the value of several chemicals for weeding corn under conditions prevailing in central Massachusetts and the purpose of this paper is to report the results of this work.

There are two distinct methods of weeding corn with chemicals, either as pre-emergence or as post emergence applications. The pre-emergence technique with 2,4–D first described by Anderson and Wolf (3, 4) has a distinct advantage because of its exceptional weed killing properties against most annual grasses and broad leafed weeds. As opposed to this, post emergence applications of 2,4–D have little or no effect on grasses at concentrations that are safe to use on corn.

Various formulations of 2,4–D are available as salts, amines and esters. Ellis and Bullard (13) found that the various forms of 2,4–D did not affect the number of marketable ears, yield or stand when 0.7 pound of 2,4–D acid was applied to Golden Cross Bantam sweet corn as a side spray to plants 15 to 18 inches high. The ester forms are not generally considered safe in amounts greater than 0.25 pounds 2,4–D acid per acre when applied as direct foliar sprays to corn (16). Rahn and Schell (28) obtained equally good weed control with 1.5 pounds of the various forms in pre-emergence applications with some seedling injury caused by an ester but this damage disappeared within a week.

Most investigators have found that 1.5 pounds of 2,4–D acid is sufficient to give good weed control with maximum safety (4, 5, 16, 27, 28) although under certain conditions it is clear that larger amounts may be tolerated (14, 22). Most of the evidence, however, shows that 0.5 pound 2,4–D acid is the maximum safe dosage tolerated by corn as a direct foliar spray when the salt or amine forms are used (12, 16, 22, 23) and 0.25 pound 2,4–D acid when the ester forms are employed (16, 22). Van Alstine (33) has reported satisfactory weed control with acre applications as low as 0.05 to 0.10 pound of 2,4–D acid in the ester form.

[1]Contribution No. 704 of the Massachusetts Agricultural Experiment Station.

The chemicals used in these experiments were kindly supplied by the following companies: Dow Chemical Company, Aero Cyanamid Company, Sherwin Williams Company, and American Chemical Paint Company.

Great differences exist in regard to the volume of water used per acre for applying 2,4–D. Recently extremely low volume applications (as low as 2 to 5 gallons per acre) have been suggested (12, 16, 22, 29, 33). Smith (31) has shown, however, that 2,4–D was most effective and a higher percentage of spray was intercepted and retained at a volume rate of 12.7 to 25.5 gallons per acre. Rates of 40 to 125 gallons per acre were less effective, and there was a progressive decrease in magnitude of response as the volume was reduced below 12.7 gallons per acre. Moreover, sprays of relatively large-droplet size were more effective than those of smaller-droplet size.

It is apparent that some investigators believe that corn larger than 6 inches tall is less susceptible to damage from 2,4–D (22), some say that it should not be treated until 12 to 18 inches tall (12, 22), and some evidence has been presented to the effect that the yield of corn was reduced from one-third to one-half or more by treatments up to the milk stage (38). In general there is a feeling that corn at these stages of development is less harmed by a sidespray than with a direct foliar spray. Dearborn *et al* (10) have reported that yields of Golden Cross Bantam sweet corn were not affected when it was treated at 10 different stages of growth with 0.4, 0.6, or 0.8 pound of 2,4–D acid per acre. Wolf *et al* (40), Van Geluwe and Tafuro (34) and Shafer *et al* (30), however, indicate that young corn plants are more tolerant than older ones. Anderson and Wolf (4) have applied as much as 2.5 pounds of 2,4–D acid to corn when 50 per cent of the seedlings were above ground without a significant reduction in stand or yield.

Some workers indicate that in pre-emergence applications better weed control and less seedling injury result when the 2,4–D application is delayed for 5 to 8 days after planting (3, 4, 5, 16, 40); whereas others report no significant difference between pre-emergence applications made 1 and 5 days after seeding (28). It has been demonstrated by Anderson and Wolf (4) that susceptibility of corn seedlings to 2,4–D decreases rapidly up to the eighth day after planting.

Post-emergence applications have little or no effect on grasses whereas pre-emergence applications do give more (3, 34, 36) or less (22, 26) control of annual grasses. Where good control of annual weeds has been obtained with the pre-emergence technique the land remains free of weeds for 3 to 6 weeks (2, 3, 34, 36).

Many workers have indicated that post-emergence 2,4–D treatments are apt to cause corn stalks to become brittle, resulting in breakage and a tendency to lodge more than untreated plants. Havis and Sweet (17) report less lodging in 2,4–D treated North Star and more lodging in treated Iona sweet corn. Dearborn *et al* (10) found no association between lodging and treatment. Hamner *et al* (14) have reported that pre-emergence spraying increased the development of brace roots and suggest this treatment to prevent lodging. They point out that this effect is in direct contrast to the inhibition of brace roots when 2,4–D is applied as a foliar spray. Ellis and Bullard (13) indicate that certain varieties produce an increased number of feeder roots with a post-emergence spray.

Considerable difference of opinion exists as to the effect of the 2,4–D

on yields. The New Jersey Experiment Station has conducted wide-scale pre-emergence tests with field corn for three years. They indicate that little or no reduction in yields is to be expected on the heavier soils from a 1 to 1½ pounds 2,4–D acid application applied 5 to 12 days after the corn is planted (40). Warren and Hernandez (36) in one test, however, reported that a 2 pound pre-emergence application reduced yields by 12 per cent. Noll and Odland (26) reported no reduction in yield even where 3 pounds of 2,4–D were used pre-emergence. Reports also vary on the effects of post-emergence applications on yield. Some work (17) indicates that no yield reduction resulted, even when corn plants were badly malformed by the 2,4–D treatment. Dearborn (11) reports that post emergence 2,4–D applications actually increased the yield but ear size was reduced where the rate was stepped up to 1 pound of 2,4–D acid per acre.

Ellis and Bullard (13) report that leaf rolling induced by 2,4–D treatment did not result in delayed maturity, but Shafer *et al* (30) have demonstrated that spraying at the time tassels appeared did delay maturity. In one planting Warren and Hernandez (36) found that a pre-emergence application of 2,4–D delayed both emergence and maturity of sweet corn.

It is rather significant that most of the evidence indicates that it is desirable to cultivate corn in conjunction with 2,4–D treatment whether weeds are plentiful or not (11, 32, 40). It is suggested, however, that cultivation following pre-emergence treatment be delayed until corn is 15 to 18 inches tall, for stirring the soil before this may render the treatment ineffective.

Also particularly noteworthy is the fact that varieties of sweet corn differ in response to 2,4–D treatment (10, 13, 17, 22, 34). It is clear that varieties such as North Star and Seneca Dawn are very susceptible to 2,4–D injury, whereas Ioana, Lincoln, and Marcross show the least response, and Carmelcross, Spancross and Golden Cross are intermediate in this respect (17).

Anderson (5) has pointed out that pre-emergence use of 2,4–D on light sandy soils is hazardous because the emergence of seedlings was severely depressed and the control of weeds very unsatisfactory. This has also been reported by other workers (34, 40).

Weaver *et al* (37) state that rainfall occurring within 24 hours of application reduced the effectiveness of the herbicide in post-emergence applications although some workers believe that rain shortly after treatment is not detrimental if the spray has already dried on the weed foliage (1). There is a definite feeling that a heavy rain soon after pre-emergence application may be responsible for reducing the stand of plants and ultimate control of weeds (4, 5, 10, 34). It is also true that moist soil has a tendency to inactivate 2,4–D even though it may not be leached (9, 25, 35). There is also evidence that organic matter in the soil is responsible for inactivating 2,4–D (19, 25), although where an addition of 4,000 pounds of cow manure reduced persistency, 8,000 pounds reduced the rate of inactivation (9). Soil pH is another factor suspected of having some influence on persistency of 2,4–D in the soil but the evidence is conflicting (18, 19, 25). There is general agree-

ment that higher temperatures tend to dissipate 2,4–D more quickly from the soil (9, 18).

Briggs and Wolf (8) have demonstrated the possibilities of controlling weeds in corn with cyanamid. They found that it was possible to eliminate the first and possibly the second cultivations with a pre-emergence application of 400 pounds of cyanamid. This treatment significantly reduced weeds and increased yields.

Certain of the phenolic compounds also appear to be promising weed control agents in corn (6, 7, 27). While still strictly in the experimental stage it is apparent that some of the di-nitro weed killers and the pentachlorophenates may be safer than 2,4–D in pre-emergence applications.

Reports of Experiments

Various chemicals, both wet and dry, were used in these experiments in pre-emergence as well as post-emergence applications. The rates of application have been varied. Particular attention has been given to 2,4–D because of the noteworthy results reported by other investigators who have used this chemical.

The 1945 Tests:—In 1945 a 1 per cent solution of Sinox (sodium dinitro-ortho cresylate) was sprayed on about a quarter acre section of a sweet corn breeding nursery at the rate of 100 gallons per acre. Ammonium sulfate was added to the Sinox solution at the rate of 2 pounds per 100 gallons to serve as an activator. The corn consisted of many types of early inbreds and was 1½ to 2 inches high at the time of spraying. A post-emergence spray of 2,4–D (Weedone) was applied to a planting of Golden Cross Bantam sweet corn when the plants were about 14 inches tall. The 2,4–D was applied at a strength of 1000 ppm at the rate of 150 gallons per acre.

Sinox proved to be very effective in controlling many broad-leafed weeds (20), especially when applied while the leaves were small, that is, ½ to ¾ inch tall, but the effect on grassy weeds was negligible. Little or no harm resulted to corn when the applications were made while the plants were in the spike stages and before the leaves had unfolded. Later spraying proved to be hazardous, especially where high temperatures followed the Sinox application.

The 1000 ppm application of 2,4–D was very effective in controlling pigweed, galinsoga, purslane, and lamb's quarters in a planting of Golden Cross Bantam sweet corn, but annual grasses were not visibly affected. Leaves of the corn took on a very curious appearance a few days after the 2,4–D application. The leaves were rolled, many took an upright pose, and many of the stalks became curved. After 4 weeks, however, the plants had grown out of this malformed condition and later produced a normal crop.

The 1946 Tests:—In 1946 the Sinox treatment was again used in the sweet corn nursery as well as in the hybrid sweet corn testing plots. A test with Sinox was also made in a block of approximately 2 acres of Carmelcross corn. The sodium salt of 2,4–D (500 ppm) at the rate of 100 gallons per acre was sprayed on a crossing plot involving 25 early sweet corn inbreds when the plants were about 2 inches tall.

The work in 1946 emphasized the fact that sweet corn seedlings tolerate a 1 per cent Sinox spray for a short time after they emerge from the soil but the plants are very subject to injury after the leaves unfurl from the sheath. One vegetable grower sprayed a 2-acre field of Carmelcross corn when the plants were about 8 inches tall, causing a great deal of crop injury. Although none of the plants were killed, maturity was delayed for several days and a lower price realized on the crop.

A collection of 25 sweet corn inbreds was not visibly affected by a 500 ppm spray of the sodium salt of 2,4–D, applied at the rate of 100 gallons per acre when the plants were 2 inches tall. Young broad-leafed weeds were killed but grasses were unaffected. A small planting of sweet corn was treated with 2,4–D at the rate of 2 pounds per acre immediately after planting and this demonstrated very clearly the possibilities of pre-emergence weeding with chemicals (21).

The 1947 Tests:—In 1947 the variety Seneca Chief was used in all of the experiments. The sodium salt of 2,4–D was applied just after planting as a spray at the rate of 2.75 pounds, acid equivalent, per acre. Other treatments applied at this time were 40 pounds of a 5 per cent triethanolamine salt 2,4–D dust, and 100 gallons of No. 2 fuel oil. The amine salt of 2,4–D was also applied to other plots 5 days after planting, at the rate of 1 and 2 pounds, acid equivalent, per acre. Dow Selective Weed Killer (2 pints per 100 gallons) and the amine salt of 2,4–D at 600 ppm and 1200 ppm were applied later as direct foliar sprays when the corn was about 8 inches high. Some small-scale tests were also made using a Hauck Little Giant flame gun as well as a Sizz Weeder.

The most outstanding feature of this year's results was the complete control of all weeds except smartweed in the plots given a pre-emergence treatment with 2.75 pounds of 2,4–D. (Figs. 1 and 2). Many of the corn seedlings in these plots were twisted and the seedling leaflets did not unfold properly from the sheath. Approximately 15 per cent of the plants were affected so badly that they did not develop properly or form ears. Weeds were so well controlled in this planting that cultivation was unnecessary.

Weed control in plots treated with 2,4–D dust was extremely variable because of difficulties in distributing the dust uniformly. Drift to sensitive crops, such as peppers, in adjoining fields makes the use of 2,4–D dusts particularly hazardous.

The pre-emergence application of fuel oil gave very satisfactory weed control and did not affect germination. This treatment kept the corn free of weeds for over 3 weeks. One per cent Dow Contact Weed Killer was not as effective as kerosene but was much more economical. Later exploratory tests indicated that corn tolerates Dow Contact Weed Killer in applications up to 3 gallons per acre with practically perfect control of annual weeds. Pre-emergence applications of Stoddard Solvent at planting time were of little or no value.

Post-emergence applications of 2,4–D or Dow Selective Weed Killer were very effective in controlling broad-leafed weeds, but had no visible effect on grasses. Post-emergence applications of the amine form of

FIG. 1. This plot received 2,4-D at the rate of 2 pounds per acre, applied 1 day after planting. Practically all weeds were controlled except smartweed. This plot was not cultivated.

FIG. 2. Uncultivated and unsprayed check plot.

2,4–D at 600 and 1200 ppm concentrations caused no malformation of Seneca Chief sweet corn where the material was applied to plants 8 inches high.

Weeding with a flame thrower was effective, but this treatment cannot be used on very young corn. Corn must be 8 to 10 inches tall before the crop is adapted to this type of weed control.

Cyanamid at the rate of 750 pounds per acre kept the land free of weeds for approximately 4 weeks. This treatment did not reduce the stand, but seedlings were yellow as they emerged from the soil. Later, it was apparent that the cyanamid acted as a stimulant to the corn. This effect was reflected very clearly in the yield of grain corn in a cooperative-farmer-experiment.

The 1948 Tests:—In 1948 more comprehensive experiments were conducted in view of the promising results of previous years as well as many successes reported by other investigators. Thirty treatments were applied to North Star sweet corn and these were replicated three times. The plots consisted of three 30-foot rows each and the corn was planted by hand with the rows spaced 3 feet apart and the seed 9 inches apart in the row. Records were taken from the middle plot row only. The soil was a Scarborough very fine sandy loam with an impervious subsoil and was considered to be low in fertility. It was prepared in the normal manner and a 5-8-7 fertilizer was broadcast at the rate of 2,000 pounds per acre. The corn was planted on June 15. Sprays of 2,4–D, both the sodium salt and the butyl ester, were applied on some of the plots 1 day after planting, and on other plots 6 days after planting, when about 12 to 15 per cent of the corn plants had emerged. The germination period was quite cool and the soil very wet. Granular cyanamid, Dow Contact Weed Killer, and Dow general plus fuel oil were also sprayed on some plots one day after planting. On July 8, when the corn was about 8 inches high and weeds 2 to 4 inches high, 2,4–D sodium salt and 2,4–D butyl ester were applied to previously untreated plots as foliar sprays. All of the sprays were applied with a hand pressure sprayer at the rate of 100 gallons per acre. The treated plots were cultivated only once, on July 29, and the check plots were cultivated four times during the growing season.

Results are presented in Table I.

In another experiment 10 varieties of sweet corn were planted in nine blocks to determine whether 2,4–D had any differential effect on them when applied as a pre-emergence treatment. The sodium salt of 2,4–D was applied on the day of planting at the rates of 1 and 2 pounds acid equivalent per acre and these plots were cultivated once, on July 29, and the checks were cultivated four times. The plots were replicated three times. The following varieties were used in this test: Seneca 60, Spancross, Secena Dawn, Early Golden, North Star, Marcross, Carmelcross, Pilgrim, Lee, and Golden Cross Bantam.

A large weed population was present rather uniformly consisting of chickweed, lamb's quarters, purslane, pigweed, smartweed, wiregrass, galinsoga and a rather small percentage of ragweed. It is clearly apparent from Table I that the various chemicals had no significant effect on seed germination. It should be emphasized that the soil type

TABLE I—EFFECT OF CHEMICALS ON WEED STAND AND ON GERMINATION, DEVELOPMENT AND YIELD OF NORTH STAR SWEET CORN

Treatments (Rates Per Acre)	Germination (Per Cent)	Weeds Per Square Foot (Number)	Days to 50 Per Cent Silking (Number)	Plants Lodged Per Plot (Number)	Marketable Ears	
					Average Size (Pounds)	Yield Per Plot (Pounds)
Applied One Day After Planting						
Cyanamid						
600 pounds	88	37	54	8	0.57	22
2,4-D, Sodium Salt						
0.5 pound	88	23	53	11	0.53	18
1.0 pound	86	26	52	8	0.57	24
1.5 pounds	85	18	51	5	0.58	25
2.0 pounds	87	18	50	4	0.57	25
3.0 pounds	84	15	51	6	0.59	26
2,4-D, Butyl Ester						
0.5 pound	87	29	51	8	0.55	21
1.0 pound	89	29	52	11	0.53	18
2.0 pounds	87	13	52	5	0.60	23
Dow Contact Weed Killer						
1 gallon	89	43	52	8	0.56	23
Dow General						
1 pint + 1 gallon fuel oil	87	30	50	9	0.62	28
1 pint + 2 gallons fuel oil	86	38	53	12	0.54	19
Applied Six Days After Planting						
2,4-D, Sodium Salt						
0.5 pound	90	12	52	4	0.61	25
1.0 pound	86	8	53	8	0.56	21
1.5 pounds	88	8	53	10	0.55	23
2.0 pounds	86	10	53	9	0.58	22
3.0 pounds	90	6	53	5	0.60	24
2,4-D, Butyl Ester						
0.5 pound	89	20	52	7	0.62	24
1.0 pound	89	15	52	6	0.59	22
2.0 pounds	87	7	52	4	0.58	24
Applied July 8—Corn Eight Inches High						
2,4-D, Sodium Salt						
0.50 pound	—		56	10	0.48	14
0.75 pound	—		54	5	0.55	20
1.00 pound	—		54	2	0.52	19
2.00 pounds	—	Covered with Grasses	55	2	0.51	15
2,4-D, Butyl Ester						
0.15 pound	—		55	4	0.51	17
0.25 pound	—		53	2	0.55	17
0.50 pound	—		57	2	0.50	17
0.75 pound	—		52	4	0.46	13
1.00 pound	—		56	5	0.43	12
Control—Cultivated four times	88	0	51	20	0.60	27
L.S.D. 5 per cent	**	11	**	**	0.09	7.3
1 per cent		15			0.12	10.3

**No significant difference.
All figures are averaged of three replications.
Treated plots were cultivated once on July 29.

in the experimental area was a very fine sandy loam, and a heavy nature, and very retentive of moisture. This type of soil has been considered safest to use in conjunction with pre-emergence applications of 2,4–D on corn.

Large and significant differences exist among the various treatments in regard to their capacity for controlling weeds. The 6-day delayed, pre-emergence treatment was especially noteworthy in inhibiting weed growth and delaying the appearance of a late crop of weeds. None of the pre-emergence 2,4–D treatments were effective against smartweed.

Perhaps the most desirable treatment in respect to expense, weed control, and safety was the 2,4–D sodium salt, 1½ pounds acid equivalent per acre.

The Dow Contact and Dow General treatments were effective for a period of about 2 weeks but after that were of little value. In a later experiment it was rather evident that 2 to 3 gallons of Dow Contact Weed Killer per acre applied immediately after planting corn was relatively safe and weed control was excellent. Plots receiving this treatment were free of weeds for approximately 6 weeks.

Post emergence applications of 2,4–D were of little value in view of the large grass population. Competition from grasses probably accounts for a great deal of the loss in yield from these treatments. They caused a gerat deal of malformation of the corn plants expressed as leaf rolling, upright leaf pose, fasciation of brace roots, and so on, which increased in severity with increasing rates of 2,4–D (Figs. 3 and 4). In this respect the butyl ester was estimated to be roughly 2.5 times as toxic as the sodium salt on a 2,4–D acid-pound basis. Where 0.15 pound of the butyl ester showed little or no toxic influence on corn, 0.25 pound gave a slight response and 0.5 pound produced severe malformation. 1 pound even dwarfed the corn to some extent and caused very extreme malformation of leaves.

In another experiment it was evident that serious malformation of the corn did not result when the 2,4–D was applied as a side spray even though some of the spray did wet the basis of the plants.

Fig. 3. Unsprayed check of North Star sweet corn. Photo made on August 24.

Fig. 4. North Star sweet corn sprayed with 2,4–D post-emergence, as direct foliar spray when corn was 6 to 8 inches high on July 8. Rates of 0.5 pound or more of butyl ester and 1.0 pounds or more of the sodium salt resulted in very seriously malformed plants. Photo made on August 24.

Although the results in Table I indicate no significant effect of 2,4–D on germination of North Star sweet corn there was a significant effect measured where 10 different varieties were under test. The average per cent germination was 80.5 for the check, 78.9 for 1 pound of 2,4–D and 74.4 for 2 pounds of 2,4–D. The average germination for all varieties was significantly lower for the 2 pounds than for the check or the 1 pound treatment. The interaction of varieties by treatment was insignificant with respect to yield, but interaction of blocks by treatment was highly significant. This was to be expected on the basis of findings of other investigators to the effect that, in pre-emergence applications of 2,4–D, results vary with respect to soil type.

Cyanamid at the rate of 600 pounds per acre applied soon after planting corn prevented weed growth for several weeks; and later, when weeds did appear, both corn and weeds were stimulated by this treatment.

Summary

Several herbicides have been found that control weeds in fields of sweet corn for from 2 to 8 weeks. 2,4–D, post emergence, and di-nitro selective herbicides such as Sinox and Dow Selective are effective in killing broad-leafed weeds but do not affect grasses to any extent. Pre-emergence applications of 2,4–D and Dow Contact or Dow General Weedkillers controlled both broad-leafed and grassy weeds. Delaying the 2,4–D application for 6 days after planting was especially beneficial in regard to better control of weeds. The malformations associated with post emergence 2,4–D applications were much less severe when the material was applied in pre-emergence applications.

On a cost basis, 2,4–D was the cheapest material to use. However, certain weather conditions occurring soon after application of 2,4–D may be hazardous, particularly on the lighter types of soils. Results with di-nitros look very promising, but more extensive trials are necessary to determine possible hazards with these materials.

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Weed Control in Onions Grown from Sets[1]

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It has generally been considered that the principal job in the culture of onions between planting time and harvest is weed control. For generations this has been accomplished by hand labor in some form or another; usually this meant a combination of hand weeding and cultivation with wheel or shove hoes. On this basis it has been estimated that cultivating and weeding made up nearly 40 per cent of the total labor cost (5) in growing onions.

Although chemicals have been used for centuries to control weeds it is only within the last 50 years that their potential selective action was recognized. Within the last 25 years experimenters in Europe (1, 3, 4) and the United States (14, 15) found that dilute sulfuric acid was of value as a selective herbicide in onion fields. Recently Hedlin (11) and Carew and Hedlin (6) demonstrated that dilute solutions of potassium cyanate are selective for onions grown from seed and provide a toxic agent for killing annual weeds. The purpose of the experiments reported here was to study the effect of several chemicals[2] on weed control and the yield of onions grown from sets.

Materials and Methods

Experiments with Ebenezer onions were conducted on a Scarborough very fine sandy loam with an impervious subsoil in 1947 and 1948. The soil was moderately fertile and the pH ranged from 5.7 to 6.0.

A Hauck "Little Giant" flame gun was used for flaming weeds and this was carried at a rate of approximately 2.5 miles per hour. The Cyanamid dust treatment was with the material known as Aero Cyanamid special grade and in post-emergence treatments no special effort was made to keep the dust off the plants.

The Sinox used was of the old formulation with sodium dinitro-ortho cresylate as the active ingredient. A 1 per cent spray of Sinox with 1 pound of ammonium sulfate to 100 gallons of water was used as a direct spray on the onion plants as were Dow selective herbicide (2 pints to 100 gallons) and sodium pentachlorophenate (0.5 per cent solution). 2,4–D was applied at the rate of 2.0 pounds (acid equivalent) in 100 gallons of water using the 80.5 per cent sodium salt. Several strengths of potassium cyanate (KOCN) were used both as direct foliar and as side sprays. The brand name of this material was Aero Cyanate Weedkiller. Isopropyl phenyl carbamate (IPPC) was used as a pre-emergence application at the rate of 5 pounds per acre with sand as the diluent and Stoddard solvent with tributyl phosphate as the co-solvent as a second treatment. The Stoddard solvent, IPPC

[1]Contribution No. 692 of the Massachusetts Agricultural Experiment Station.
[2]The various chemicals used in these experiments were kindly submitted by the following: American Cyanamid Company, Dow Chemical Company, Pittsburgh Plate Glass Company and Standard Agricultural Chemicals, Inc.

mixture was applied at the rate of 100 gallons per acre. A few exploratory treatments were given but these were not replicated. The sprays were applied with a Brown open-hed No. 4 hand pressure sprayer fitted with a No. 8004 spraying systems fan-type nozzle and the speed of application was regulated so that the plots were covered twice at any given application to assure as uniform coverage as possible.

In 1947 five replications and in 1948 three replications were used for each treatment and were laid out in randomized blocks. The plot size used was six rows, 15 feet long, with rows spaced 15 inches apart. The onion sets were spaced 3 inches apart in the row.

The following weeds were present abundantly and more or less uniformly throughout the experimental area: purslane, chickweed, shepherd's purse, smartweed, lamb's quarters, pigweed, galinsoga and wiregrass. Cultivation and hand weeding were not practiced on the chemically treated plots at any time during the season.

Yields of 1948 were considerably lower than those of 1947 and this might be expected in view of the inclement weather experienced during the first half of the growing season in 1948. Commercial fields experienced a considerable amount of onion blast (12) but the experimental plots were free from this trouble. It is not suggested that this was the result of any of the herbicidal treatments.

Results and Discussion

The results of the 1947 and 1948 experiments are presented in Tables I and II. While some of the treatments in 1947 were very effective in controlling weeds, it is apparent that they were detrimental to the yields since the cultivated plots yielded more than those otherwise treated. All of the differences are significant at the 5 per cent level and only the plots treated with Cyanamid and flame come within the least significant difference range at the 1 per cent level. The yields of scraped plots (very shallow cultivation) come within the range at both levels but even here the yield is 10.5 per cent less than that produced by deep cultivation. The lower yield in the scraped treatment might be attributed to the pre-emergence Stoddard solvent spray but

TABLE I—The Effect of Several Weed Control Agents on the Yield of Set Onions in 1947 (Planted April 17, Harvested July 20)

Treatments (Five Replications)	Rate Per Acre	Number of Applications	Yield of U.S No 1 Onions (Bushels Per Acre)
1 Flamed with Weed Burner	———	2	535
2. Sodium Pentachlorophenate 0.5 per cent solution	90 gal	2	424
3. Cultivated	———	4	679
4. Stoddard Solvent pre-emerg followed by scraping	100 gal	1 4	607
5. Dow Selective Herbicide (2 pints to 100 gallons)	100 gal	2	479
6 Cyanamid Dust	50 lbs	5	562
7 1 per cent Sinox + 1 pound $(NH_4)_2SO_4$ too 100 gallons	100 gal	2	501
L S.D. 5 per cent			107
1 per cent			146

TABLE II—THE EFFECT OF SEVERAL WEED CONTROL AGENTS ON THE YIELD OF SET ONIONS IN 1948* (PLANTED APRIL 22, HARVESTED JULY 29)

Treatments* (Three Replications)	Rate Per Acre	Number of Applications	Weeds Per Sq Ft July 14	Yield U.S. No. 1 Onions (Bushels Per Acre)
1. Cultivated	———	3	0	420
2. Cyanamid dust (pre-emergence) +	75 lbs	1	14	392
KOCN 1 per cent)	80 gal	4		
3. Cyanamid dust (pre-emergence) +	150 lbs	1	7	413
KOCN 2 per cent	80 gal	4		
4. IPPC in sand (pre-emergence) +	5 lbs	1	16	388
KOCN 1 per cent	80 gal	3		
5. Na salt of 2,4-D (pre-emergence) +	2 lbs	1	2	287
KOCN 1.5 per cent on plants	80 gal	3		
6 Cyanamid dust	50 lbs	3	8	265
7. Granular Cyanamid (pre-emergence) +	600 lbs	1	10	324
KOCN 3 0 per cent on plants	80 gal	2		
8. IPPC in oil (pre-emergence) + KOCN	5 lbs	1	16	362
1 per cent.	80 gal	3		
9. KOCN 2 per cent	80 gal	4	6	413
10. KOCN 2 per cent on plants	80 gal	4	4	349
L.S.D. 5 per cent			6	72
L.S D. 1 per cent			8	99

*These were post-emergence treatments except where otherwise noted.

this is doubtful since the onions showed no above-ground growth for at least 10 days after spraying and Stoddard solvent is completely evaporated from the soil in a shorter time than this. No benefit in weed control resulted from this application of Stoddard solvent in mid-April before weeds had made their appearance. The results here are in line with those of Thompson (16) who found that onions grown on cultivated plots over a period of 6 years yielded 7.69 per cent more than those grown on scraped plots.

Flame cultivation was effective in controlling weeds. The onions appeared to be severely injured after the first treatment with flame but recovered in a few days. It was clearly apparent that the flame must be kept moving at a steady rate and not slower than 2.0 miles per hour to prevent excessive injury.

The 0.5 per cent solution of sodium pentachlorophenate as a foliar application controlled broad-leafed weeds readily with little or no effect on annual grasses. This material damaged the onion leaves more than any other treatment in the experiment. From tests with onions in the greenhouse and with sweet corn in the field it is evident that the pentachlorophenates are better adapted as pre-emergence herbicides. This is in line with the theory propounded by Crafts (8). Bakke (2) and Fitch (10), however, reported very promising results with this material as a post-emergence spray on onions in Iowa.

Apparently selective di-nitro herbicides do not have the degree of selectivity for onions here that is reported in the far-west. Dow selective herbicide and Sinox proved to be quite toxic to the onions and their inability to control grasses to any extent was also a serious drawback. In a cooperative experiment with one grower, however, 2 acres of onions were saved that otherwise would have grown up in weeds because of a labor shortage. Even so, this block yielded about 70 per cent as well as other comparable fields. The sacrifice in yield was probably due to early weed competition as well as later injury from Sinox.

Weeds in the plots treated with Cyanamid dust in post-emergence

applications were kept well under control in both years of the tests. It was not possible to predict accurately how much damage would accrue at any particular time of treatment. Best weed control resulted when weeds were wet with rain or dew at the time of application followed by clear, warm weather for several days. As might be expected most damage resulted to the onions under the same conditions that promoted best weed control. The grower previously mentioned also treated a 2-acre block of onions several times with Cyanamid dust in an effort to "save the crop". This block also yielded about 70 per cent as well as would have been expected had the field received proper attention. The grower felt well repaid, however, in view of the fact that little or no crop would have been realized without these treatments. The Cyanamid dust pre-emergence applications were particularly beneficial in controlling the first crop of weeds, especially at the 150-pound-per-acre rate. This effect was lost, however, in several weeks and it was then that potassium cyanate applications were especially useful and noteworthy.

Granular Cyanamid as a pre-emergence application at the rate of 600 pounds per acre controlled weeds very effectively for a period of 3 to 4 weeks but after that the weeds came in abundantly. This treatment reduced the stand of plants somewhat and caused a great deal of leaf injury during the early part of the season. Later these plants recovered and appeared to grow in a normal manner even though it was apparent that this rate of application was too high for safety on onions.

A 2 per cent solution of KOCN was very effective in controlling small weeds but this material should be applied as a side spray and *not* as a direct foliar spray. It was not possible to predict the amount of leaf injury from foliar sprays that might result from spraying with KOCN based on previous treatments for the attendant injury was quite variable at the various times of treatment. It was very evident that 1 or 2 per cent solutions of KOCN were relatively ineffective in controlling large weeds. This was especially true of annual grasses and lamb's quarters. These weeds were not affected by the sprays after they had developed to more than ½ to ¾ inch in height so that it is essential to begin spraying just as soon as the weeds make their first appearance and proceed with later crops of weeds on the same basis.

A number of growers in this area used KOCN successfully for weeding onions in 1948. They were all very pleased with the results and indicated their intention of using it again. One man treated 30 acres of set onions three times with KOCN in addition to his usual cultivation practices and no hand weeding was necessary. Their estimates of the effects of KOCN varied from a slight decrease to a slight increase in yield. The results reported in Table II indicate an insignificant reduction in yield from a side spray of 2 per cent KOCN. It should be noted that these plots were not cultivated or hand weeded during the season and while some weeds were present at harvest time they were not of sufficient size or numbers to warrant the expense of their removal. A 4 per cent solution of KOCN was very effective in controlling larger weeds with considerably more injury to onion plants.

A pre-emergence application of 2 pounds of 2,4–D reduced the stand of weeds to about 50 per cent as compared with untreated plots during the very early season and was classed as poor weed control when compared with the plots treated with KOCN. While the 2,4–D produced no noticeable effect on the onion plants the yields from these plots were the lowest in the experiment. This is in line with other work on set onions (17).

Isopropyl phenyl carbamate did not appear to affect the development of grasses to any extent in these tests but did exert a marked depressing effect on chickweed for a period of about 3 weeks which was rather surprising on the basis of previous work (13).

A 2 per cent solution of sulfuric acid was used in some other tests with onions but the poor control of lamb's quarters, purslane and annual grasses obtained together with its hazardous nature do not permit its general recommendation. It is significant that in greenhouse tests, Crafts (7) and Crafts and Reiber (9) found that they could kill seedling grasses with kerosene or gasoline without harm to onions. In out-of-door experiments at this Station, No. 1 fuel oil (kerosene), No. 2 fuel oil, Sovasol No. 1 (white gasoline), Stoddard solvent, and Stoddard solvent at 10 per cent, 25 per cent, and 40 per cent strengths, by volume, with No. 1 fuel oil as the diluent, all proved to be very toxic to onion plants grown from sets, and plants treated with these materials were dead within 3 days.

A spray of 3 per cent Dow contact weedkiller applied to the plots just before harvest was effective in controlling weeds and promoted a faster dying back of the tops. This hastened the field-curing process somewhat without any apparent injury to the onion bulbs.

Summary

The results from tests on experimental plots and in commercial fields indicate that a 2 per cent solution of potassium cyanate at the rate of 80 gallons per acre is effective in controlling small, annual weeds in fields of set onions. Where three or four timely applications were given during the growing season no hand weeding was necessary. This herbicide should be used as a side spray and not as a direct foliar spray for the material is not sufficiently selective to permit an over-all application without reducing yields.

A pre-emergence application of 75 to 150 pounds of cyanamid dust controlled weeds well for several weeks and was a valuable supplement to the spraying program with potassium cyanate.

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The Present Status of Cycloheximide (Acti-Dione) As a Fungicide[1]

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THE antibiotic material cycloheximide (trade name Acti-dione) is one of the chemicals produced by the growth of *Streptomyces griseus*. Unlike streptomycin, cycloheximide is not actively antibiotic against bacteria but is active again many fungi. Previous reports (4) have indicated that several plant pathogenic fungi are strongly inhibited in laboratory culture when small amounts of cycloheximide are added to the culture medium.

Laboratory Assay:—Ten different fungi were grown on potato dextrose agar in petri dishes. There were five series of these plates containing 0, .2, 1, 2, 4 and 20 parts per million of cycloheximide. All 10 were strongly inhibited by 20 ppm. *Glomerella cingulata,* cause of bitter rot of apples, was the least inhibited and there was 67 per cent less growth in the medium containing 20 ppm than in the medium containing no cycloheximide. *Monolinia fructicola*, cause of peach brown rot, grew 93 per cent less on 20 ppm than on the check plates. These figures are from the average measurements of the colony diameters of four plates for each treatment after 12 days of growth. At this time, the check plates were covered to the edge of the plate so the experiment was concluded.

Other fungi which were strongly inhibited by 20 ppm were: *Pythium debaryanum* (cause of damping-off of seedlings) 92 per cent less growth than the check; *Fomes* spp. (a wood-rotting fungus) 100 per cent; *Alternaria solani* (cause of early blight of potatoes) 93 per cent; *Cladisporium cucumerinum* (cause of a leaf spot of cucumber) 77 per cent; *Colletotrichum lagenarium* (cause of bean anthracnose) 70 per cent. The *Fomes* culture was completely inhibited even by 2 ppm of cycloheximide in the medium.

Powdery Mildew Control:—Greenhouse tests have been reported which show that the material gives satisfactory control of powdery mildew of beans and roses when sprayed with concentrations as low as 2, 3, and 4 ppm. Two rose growers in the midwest who have tested the material for rose mildew control under commercial condition, report result (1). One of the desirable characteristics of the material that make it attractive to commercial rose growers is that unlike sulfur, it can be used immediately following parathion and other organic insecticides, without foliage injury. When used at concentrations below 5 ppm, spraying must be repeated at 10-day intervals, more or less depending on the weather.

Post-Harvest Brown Rot Control:—A series of three experiments was conducted this harvest season to find out if a post-harvest dip of peaches in a solution containing cycloheximide would decrease the amount of brown rot which develops after harvest. Seventy-five

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peaches were used in the three tests and three concentrations of the chemical in which peaches were soaked for different lengths of time. Concentrations used were 20, 50 and 100 ppm, and the times were 5, 10, 20, and 30 minutes. In a preliminary experiment it was found that there was more brown rot at 20 and 30 minutes than at 5 or 10 minutes in all concentrations and the control solution. It was decided, therefore, to concentrate on the 5 and 10 minute times of dipping. The table shows part of the data from these tests. The figures are the average per cent of rot of the various treatments 4 days after harvest. The peaches used were of the variety Rochester, and were picked full-ripe from trees which received no fungicide all season. The dips or soaks were made immediately following the harvest and the peaches were stored at room temperature (72 to 87 degrees F) in open bins simulating conditions in a retail store. The data in Table I are used as an

TABLE I—AVERAGE PER CENT ROT OF PEACHES FOUR DAYS AFTER HARVEST WHEN DIPPED FOR 5 OR 10 MINUTES IN SOLUTIONS OF THREE DIFFERENT CONCENTRATIONS OF CYCLOHEXIMIDE (ACTI-DIONE)

Concentration of Cycloheximide	5 Minute Dip (Per Cent)	Check (Per Cent)	10 Minute Dip (Per Cent)	Check (Per Cent)	5 Minute Dip W/WA* (Per Cent)	Check (Per Cent)	10 Minutes Dip W/WA (Per Cent)	Check (Per Cent)
20 parts per million	16	77	17	72	14	58	24	72
50 parts per million	17	75	25	75	16	58	26	72
100 parts per million	15	77	20	75	22	58	10	64

*A wetting agent, methylcellulose, was added to this series at the rate of 0.1 of 1 per cent.

example because 4 days is sufficient time for most Michigan peaches to reach the ultimate consumer. Actually the experiment was allowed to run until almost all of the peaches finally rotted. It was interesting to note that in addition to the fact that all treatments showed a lower percentage of rot than the checks, the check peaches were more than 90 per cent rotted by the brown rot organism while the treated peaches were about 10 per cent rotted by the brown rot organism, and 90 per cent by such fungi as *Rhizopus* and *Penicillium spp.* This suggests that cycloheximide controls brown rot but does not give lasting protection against the common molds which rot plant tissues.

Turf Diseases:—Some preliminary work with turf diseases indicates that cycloheximide may have value as a turf fungicide. In tests made last summer on several golf greens, the material gave as good or better control of brown patch and dollar spot, then the mercury compounds which were commonly used by the greenskeeper. A new (or at least very uncommon) disease of turf was present this year on golf greens, in Michigan. This disease is due to a species of *Helminthosporium,* and has only been reported once before as far as the authors were able to ascertain. The commonly used turf fungicides do not appear to give control of this disease. The disease was quite wide-

spread in central Michigan this year. Several golf greens badly affected were sprayed with 3 to 6 gallons of cycloheximide solution at a strength of 100 to 300 parts per million.

It was the opinion of the authors of this paper and of the greens-keeper of the course that the disease was controlled. Unfortunately, this observation could not be reaffirmed because the weather changed from hot and damp to cool and dry and the disease was checked on both the untreated and treated plots. If the material proves to be useful with further testing, there is one obvious chemical advantage over mercurial turf fungicides. Control was observed at 100 ppm and there is no injury to the turf at the highest concentration yet used (300 ppm).

Additional Suggestions:—In addition to the work summarized in this paper, other work is being done at Michigan State College on other diseases on other crops. Field tests this season on cucumber scab (2) show that cycloheximide produced the best control of any of the five fungicides tested. Decrease in amount of disease was highly significant over the check, and significantly decreased over the other materials.

Conclusions:—Cycloheximide (Acti-dione) is a material worthy of further extensive testing on various crops against fungus diseases. The material is phytotoxic in some cases and this aspect must be thoroughly tested with each new crop before more extensive trials are undertaken.

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Storage Tests with Long Island Cauliflower to Inhibit Leaf Abscission by Using Plant Growth Regulators[1]

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For a number of years requests have been received at the United States Market Pathology Laboratory, New York City, for information on the storage of Long Island cauliflower. Representatives of local refrigerating companies have reported yellowing and shedding of leaves during early weeks of storage. Small-scale storage tests were therefore initiated in 1942 by E. V. Shear, formerly of this laboratory, and were continued during 1943 and 1944.

During 1943 and 1944 marked reduction of leaf abscission was obtained by dipping the heads in 1–400 or 1–800 naphthleneacetic acid, at the time of storage. Similar results were obtained by Carolus, Lee, and Vandermark (1) of the Michigan Experiment Station by treating heads in kraft bags by means of shredded paper impregnated with various concentrations of naphthaleneacetic acid and by spraying heads with a solution of naphthaleneacetic acid.

Storage tests with Long Island cauliflower were renewed on a larger scale in 1947 and continued through 1948. Emphasis was placed on the use of plant growth regulators to prevent leaf abscission. The present paper summarizes the results obtained during those two seasons.

Experiments of 1947

Two tests were conducted during 1947. In the first one the growth regulators were applied as sprays; in the second they were applied by adding treated shredded paper to the crates. In the first test the cauliflower was placed in storage in New York City at 33 degrees F and 90 per cent relative humidity on the day of harvest; and in the second test, on the day after harvest.

Test 1947–1:—The test was made with 34 crates (388 heads). Two spray treatments were used: (a) a 50 ppm solution of the amyl ester of 2,4–dichlorophenoxyacetic acid (2,4–D) with ½ per cent of Tween 20 co-solvent in water; and (b) a similar solution containing 50 ppm of an equal mixture of 2,4–D and naphthaleneacetic acid (NA). All treated lots were sprayed at the time of tying, 2 weeks before harvest. Half of the heads so treated also received a spray application immediately after crating. Unsprayed cauliflower tied and harvested with the treated lots was used as checks.

Replicate crates were examined at the end of 2, 4, and 6 weeks of storage. As the crates were examined each head was carefully lifted,

[1]This is a report of studies made under the Research and Marketing Act of 1946. The work was conducted under the general supervision of Dr. James S. Wiant. The plant growth regulators were supplied by Dr. J. W. Mitchell, Beltsville, Md. Acknowledgment is here made to Mr. H. Meyjes, Calverton, Long Island, and to the officers of the Hermance Storage and Refrigerating Company and the Merchants Refrigerating Company of New York City for the use of their storage facilities.

held by the curd, shaken gently three times with a twisting motion of the wrist, after which fallen leaves were counted. The results of the test are summarized in Table I.

TABLE I—LOSS OF LEAVES BY ABSCISSION FROM LONG ISLAND CAULIFLOWER TREATED WITH PLANT GROWTH REGULATORS AND STORED AT 33 DEGREES F (FIRST TEST OF THE 1947 SEASON)

No. Applications	Two Weeks' Storage			Four Week's Storage			Six Weeks' Storage		
	No. Heads in Treated Crate	No. Leaves Lost By Abscission		No. Heads in Treated Crate	No Leaves Lost By Abscission		No Heads in Treated Crate	No. Leaves Lost By Abscission	
		Total Per Crate	Average Per Head		Total Per Crate	Total Per Head		Total Per Crate	Average Per Head
Check Untreated									
—	13	119	9.2	12	159	13.2	12	249	20.8
—	12	85	7.1	12	195	16 2	12	280	23.3
—	12	87	7.2	12	145	12.1	11	280	25.5
—	14	90	6.4	12	173	14 4	14	222	15.9
Amyl ester of 2,4-D									
1	11	18	1.8	10	9	0 9	12	68	5 7
1	10	10	1.0	10	13	1.3	12	41	3.4
2	10	15	1.5	10	8	0.8	11	17	1 5
2	10	4	0.4	11	5	0.5	10	11	1 1
2,4-D + N A									
1	10	16	1 6	12	24	2.0	10	28	2.8
1	14	32	2.3	10	34	2.1	—	—	—
2	9	12	1.4	12	7	0.6	12	32	2 7
2	14	19	1.4	—	—	—	10	13	1.3

At the 2-week inspection the curds were generally firm, white, and compact. An occasional head showed some slight decay. The leaves were generally fairly fresh and green. No difference other than that due to leaf abscission was noted between the several treated and untreated lots. Abscission was serious in the check crates, namely 85 to 119 leaves lost per crate, or an average of 6.4 to 9.2 leaves lost per head. In the treated lots an average of 0.4 to 2.3 leaves per head were lost by abscission. There was no commercially significant difference noted between the two treatments although slightly better results were secured from two applications than from a single spray treatment. The treated heads were judged to be of U. S. No. 1 grade, whereas the checks were considered to fall below that grade because of insufficient number of leaves to protect the heads from bruising.

It is interesting to note that observations made on 12 heads selected at random from the 12 crates of this inspection and held an additional 6 weeks at 42 degrees F showed almost complete abscission in the check heads and practically no further abscission in the treated heads. The leaves of the treated heads actually rotted off without the formation of an abscission layer.

At the 4-week inspection the cauliflower in all lots was found little changed from its appearance at the 2-week inspection, with the possible exception that it had a slightly less fresh appearance. The treated heads showed about the same amount of leaf abscission as was noted 2 weeks

earlier. These crates were considered to be still in salable condition. The untreated checks, however, showed a loss of 159 to 195 leaves per crate or an average of 12.1 to 16.2 leaves per head. They were judged to be unsalable because of this loss of leaves.

At the 6-week inspection the cauliflower in all crates showed mold growth on the jacket leaves and some of the exposed areas of the curds. Detailed examination showed various degrees of spotting and decay of leaves and curds by bacterial soft rot, Sclerotinia rot, and Alternaria rot so that none of the crates were considered salable. There was slightly more leaf abscission in the treated lots than was noted earlier. Leaf abscission was much worse in the checks than that found at earlier inspections, amounting to 249 to 280 leaves per crate, or an average of 15.9 to 25.5 leaves lost per head.

Test 1947–2:—This test included five crates treated after crating with 50 grams (approximately 2 ounces) per crate of shredded paper impregnated respectively with the following: (a) check (untreated paper); (b) methyl ester of naphthaleneacetic acid (NA) at the rate of 10 grams per 1000 grams of paper; (c) like (b), but at the rate of 50 grams per 1000 grams of paper; (d) amyl ester of 2,4–dichlorophenoxyacetic acid (2,4–D), 10 grams per 1000 grams of paper; and (e) like (d), but at the rate of 50 grams per 1000 grams of paper. An attempt was made to have the paper in contact with all exposed portions of the heads, but complete coverage was of course impossible without opening the crates. The five crates were stored for 4 weeks at 33 degrees F and were then examined as in the first test. A summary of the results is shown in Table II.

TABLE II—Loss of Leaves by Abscission From Long Island Cauliflower Treated With Plant Growth Regulators in Shredded Paper and Stored Four Weeks at 33 Degrees F (Second Test of the 1947 Season)

Plant Growth Regulators Used	Application Rate per 1000 Grams Paper (Grams)	No. Heads Per Treated Crate	No. Leaves Lost By Abscission	
			Total Per Crate	Average Per Head
Untreated paper		12	137	11.4
Methyl ester of N A	10	13	27	2.1
Methyl ester of N A	50	12	46	3.8
Amyl ester of 2,4-D	10	12	32	2.7
Amyl ester of 2,4-D	50	12	18	1.5

At removal no significant difference other than leaf abscission was seen in the five lots. The curds were firm, white and compact and the leaves were fresh and green. No decay was present. No commercially significant difference was noted between the four treated lots. They lost from 18 to 46 leaves per crate or an average of 1.5 to 3.8 leaves per head. The check crate however lost 137 leaves or an average of 11.4 leaves per head.

It was noted that the abscission of the treated leaves occurred fairly consistently on the sides untouched by the shredded paper, although an occasional head lost leaves all around the stem. In addition some of the treated leaves showed half of the abscission layer well formed and

the other half not formed or only partially formed. The leaves with incomplete abscission layers were at the edges of the areas untouched by the paper, thus suggesting the need for having each leaf touched by the paper if good control is to be achieved.

Experiments of 1948

Three tests were made in 1948. The plant growth regulator used in each instance was the amyl ester of 2,4–dichlorophenoxyacetic acid (2,4–D). This was applied either as a water-solution spray containing 50 ppm 2,4–D with ½ per cent of Tween 20 co-solvent added, or as shredded oiled apple paper impregnated with 10 grams 2,4–D per 1000 grams of paper. As during the previous season the spray was applied with a hand sprayer. When sprayed individually each head was given a thorough drenching with the spray material. When sprayed after crating, all exposed parts of the heads were given a thorough drenching.

The shredded paper used in tests 1948 – 1 and 1948 – 3 was applied at the rate of 150 grams (approximately 6 ounces) per crate, and in test 1948 – 2 at the rate of 200 grams per crate. This was spread throughout the crate, giving each head as complete a coverage as possible. In all three tests the cauliflower was treated, trucked to New York City, and there placed in cold storage (33 degrees F and 90 per cent relative humidity) on the day of harvest. In making all inspections after designated storage periods the heads were shaken individually, as has been described for the previous year, to determine the extent of leaf abscission.

Test 1948 – 1:—The first test of 1948 was made with 12 wire-bound crates, or 132 heads of cauliflower, harvested on November 9. In three crates the heads were sprayed after they had been harvested but immediately before packing; in three crates they were sprayed immediately after packing; shredded paper was added to three crates; and a fourth lot of three crates was left untreated as checks. Replicates were thus available for the removal of one crate of each treatment at the end of each of the 2-, 4-, and 8-week storage periods. A summary of the results is presented in Table 3.

At the 2-week inspection the curds of all lots were generally firm,

TABLE III—Loss of Leaves by Abscission From Long Island Cauliflower Treated With the Amyl-ester of 2,4-D and Stored at 33 Degrees F (First Test of the 1948 Season)

Method of Applying Growth Regulator	Two Weeks' Storage			Four Weeks' Storage			Eight Weeks' Storage		
	No. Heads in Treated Crate	No. Leaves Lost By Abscission		No. Heads in Treated Crate	No. Leaves Lost By Abscission		No. Heads in Treated Crate	No. Leaves Lost By Abscission	
		Total Per Crate	Average Per Head		Total Per Crate	Average Per Head		Total Per Crate	Average Per Head
Check untreated	12	0	0	12	0	0	12	63	5.25
Sprayed before packing . . .	12	0	0	11	0	0	10	0	0
Sprayed after packing.	12	0	0	12	0	0	12	1	0.08
Applied in shredded paper. . . .	12	0	0	11	0	0	10	0	0

white, and compact, with a few showing a trace of spotting. The leaves were fresh and green in all lots, although the checks showed a trace of wilting; none were abscissed. Some leaf damage from the oil was noted in the paper-treated lot. All crates were judged to be commercially salable.

At the 4-week inspection the curds in all lots were still generally firm, white and compact, although there was somewhat more spotting than at 2 weeks. The leaves were still fresh and green and none had been lost by abscission. The leaves of the paper-treated lots showed a definite loss of turgidity probably due to the oil in the paper.

After 8 weeks all four lots were seriously affected by spotting of the curds and spotting and yellowing of the leaves. One leaf was abscissed in the crate sprayed after packing while the other two treated crates lost no leaves. The untreated check crate lost 63 leaves or an average of of 5.3 leaves per head. None of the crates were considered salable at this time and only 2 heads out of the 44 inspected were considered to be of U. S. No. 1 grade.

Test 1948 – 2:—This was the most extensive test of the 1948 season. It comprised 48 crates (555 heads) harvested on November 17. Treatments were made as follows: (a) the heads in 12 crates (six nailed and six wire-bound) were sprayed with the growth regulator at the time of tying, 1 week before harvest; (b) heads in six crates (nailed) were sprayed after harvest but immediately before crating; (c) the heads in 12 crates (six nailed and six wire-bound) were sprayed after packing into the crates; (d) the heads in six crates (wire-bound) were treated with the impregnated shredded oiled paper; and (e) the heads in 12 crates (six nailed and six wirebound) were left untreated as checks.

Crates were removed from storage for inspection after holding periods of 2, 4, 5, 6, and 7 weeks, respectively. Two replicates of each type were removed at the 2-week withdrawal, one of which was inspected at removal and the other held 1 day at room temperature before inspection. At all later inspections one crate of each lot was inspected at time of removal. A summary of the inspection results is found in Table IV.

At the 2-week inspection the curds of all lots were firm, white, and compact, although a few scattered heads were spotted or slightly yellowed. Leaves were fresh and green. Slight damage by the oiled paper was observed in the paper-treated lot, but no other difference except that due to leaf abscission was noted between the various lots. Abscission was not commercially important in any of the lots, but slight amounts occurred in the untreated checks (both types of crate) and in the nailed crate sprayed after packing. It should be noted that many of the remaining leaves of the checks could be removed with a moderate pull, whereas the treated leaves were firmly attached.

In the crates removed at 2 weeks but held for an additional day at 70 degrees F, spotting of the curds and spotting and yellowing of the jacket leaves was more pronounced than on the previous day. Oil injury in the paper-treated lot was also more pronounced. Abscission

TABLE IV—LOSS OF LEAVES BY ABSCISSION FROM LONG ISLAND CAULIFLOWER TREATED WITH AMYL-ESTER OF 2,4-D AND STORED AT 33 DEGREES F (SECOND TEST OF THE 1948 SEASON)

Method of Applying Growth Regulator	Type of Crate	Two Weeks' Storage: No. Heads in Treated Crate	Two Weeks' Storage: No. Leaves Lost By Abscission: Total Per Crate	Two Weeks' Storage: No. Leaves Lost By Abscission: Average Per Head	Four Weeks' Storage: No. Heads in Treated Crate	Four Weeks' Storage: No. Leaves Lost By Abscission: Total Per Crate	Four Weeks' Storage: No. Leaves Lost By Abscission: Average Per Head	Five Weeks' Storage: No. Heads in Treated Crate	Five Weeks' Storage: No. Leaves Lost By Abscission: Total Per Crate	Five Weeks' Storage: No. Leaves Lost By Abscission: Average Per Head	Six Weeks' Storage: No. Heads in Treated Crate	Six Weeks' Storage: No. Leaves Lost By Abscission: Total Per Crate	Six Weeks' Storage: No. Leaves Lost By Abscission: Average Per Head	Seven Weeks' Storage: No. Heads in Treated Crate	Seven Weeks' Storage: No. Leaves Lost By Abscission: Total Per Crate	Seven Weeks' Storage: No. Leaves Lost By Abscission: Average Per Head
Check untreated	N*	12	6	0.5	12	87	7.25	12	60	5.0	12	182	15.2	12	136	11.3
	W†	12	17	1.4	12	86	7.2	12	114	9.5	12	174	14.5	12	123	10.25
Sprayed at tying time	N	12	2	0.2	10	6	0.6	10	1	0.10	11	4	0.36	11	1	0.09
	W	12	0	0	12	1	0.08	12	3	0.25	12	14	1.2	12	9	0.75
Sprayed at harvest, before packing	N	12	0	0	12	0	0	12	3	0.25	11	0	0	12	1	0.08
Sprayed at harvest, after packing	N	12	12	1.0	12	8	0.75	12	1	0.08	12	10	0.8	12	3	0.25
	W	12	0	0	12	8	0.75	12	5	0.4	12	7	0.58	12	1	0.08
Applied in shredded paper	W	12	0	0	10	0	0	9	0	0	10	0	0	10	0	0

*Cauliflower crated in regular nailed crates, R.R. Tariff Number 440 Long Island Cauliflower crate.
†Cauliflower crated in regular wire bound Rock Fastener Crates for Long Island cauliflower.

(not shown in Table IV), although not yet occurring in serious amount, had increased somewhat on the check heads. The treated crates, however, lost on the average less than one leaf per head.

At the 4-week inspection the heads in all lots had a good fresh appearance with the exception of the paper-treated lot and the checks. Slight spotting by Alternaria rot and bacterial soft rot was seen on a few heads, but it was not commercially important. The paper-treated lot showed damage to the leaves by the oiled paper. No significant difference in abscission was noted in the treated lots, which lost from none to eight leaves per crate. The checks lost 87 leaves in the nailed crate and 86 in the wire-bound crate, and therefore had an unattractive appearance. All spray-treated lots were judged fully salable at this time. The checks were judged unsalable as U. S. No. 1 grade because of the leaf abscission, and the paper-treated lot unsalable because of the oil injury.

At both the 5-week and the 6-week inspection the spray-treated lots were judged to be on the border line of salability, and at the 7-week inspection definitely unsalable because of the general and progressive deterioration that had occurred during storage, that is, spotting of curds, spotting, yellowing, and aging of leaves. With regard to leaf abscission the checks lost commercially significant number of leaves in both nailed and wire-bound crates at all three inspections; but the treated lots held their leaves, with an average of less than one leaf lost per head for all lots. The remaining leaves were firmly attached.

Considering all crates in this test it can be stated that very little difference in abscission due to time of application or method of application (in paper or as a spray) was observed. Thus, only in two of the treated crates was the loss as great as one leaf per head, and in most instances leaf abscission averaged less than one-half leaf per head.

Test 1948 – 3:—The final test of 1948, made with 12 wire-bound crates (144 heads) harvested on November 23, was a duplicate of the first one of the season. This included spraying immediately before crating and immediately after crating, use of impregnated shredded paper at time of crating, and an untreated check. One crate of each lot was removed at two, six, and seven weeks respectively. A summary of the results is presented in Table 5.

TABLE V—Loss of Leaves by Abscission From Long Island Cauliflower Treated With the Amyl-ester of 2,4-D and Stored at 33 Degrees F (Third Test of the 1948 Season)

Method of Applying Growth Regulator	Two Weeks' Storage			Six Weeks' Storage			Seven Weeks' Storage		
	No. Heads in Treated Crate	No. Leaves Lost by Abscission		No. Heads in Treated Crate	No. Leaves Lost by Abscission		No. Heads in Treated Crate	No. Leaves Lost by Abscission	
		Total Per Crate	Average Per Head		Total Per Crate	Average Per Head		Total Per Crate	Average Per Head
Check untreated	12	2	0.17	12	22	1.8	12	40	3.3
Sprayed before packing	12	0	0	12	0	0	12	0	0
Sprayed after packing	12	2	0.17	12	8	0.67	12	1	0.08
Applied in shredded paper.	12	0	0	12	0	0	12	0	0

At the two-week inspection the curds in all lots were firm, white, and compact, with a few showing a trace of spotting with Alternaria rot. The leaves were fresh and green in the sprayed and check lots. The leaves in the paper-treated lot showed damage from the oil in the paper. Only four leaves were lost by abscission from the 48 heads in the four crates examined. All were judged readily salable.

At both the six- and seven-week inspections all lots were seriously affected by curd and leaf spotting and by wilting and yellowing. No large amount of abscission occurred. The checks, however, lost more than the treated lots. None of the crates were judged to be still in salable condition.

Discussion

The experiments here reported indicate the effectiveness of certain plant growth regulators in increasing the storage life of Long Island cauliflower by reducing or preventing leaf drop. Loss of leaves from abscission was reduced to the point where it was commercially insignificant. Representative heads of treated and untreated cauliflower are shown in Fig. 1.

It has been brought out in these tests that the time of application had little influence on the effectiveness of the treatments. Applications made respectively at (a) 2 weeks before harvest, (b) two weeks before har-

FIG. 1. Effect of plant growth regulators on leaf abscission of cauliflower. Three representative heads illustrating the condition after 4 weeks' storage at 33 degrees F (Test 1948–2). (Left) check-untreated; (Center) sprayed 1 week before harvest, that is, at the time of tying; (Right) sprayed immediately after packing in crate.

vest and again at time of harvest, (c) 1 week before harvest, (d) at harvest before crating, and (e) at harvest after crating were all successful. Although no experiments were conducted to determine the effect of delay after harvest on the effectiveness of the treatments it would appear advisable in any commercial practice not to delay treatments any longer than necessary after the time of harvest.

The treatments were equally effective whether made by spraying the heads with solutions of the plant growth regulators or by adding treated shredded paper to the crates. It should be pointed out, however, that thoroughness of application, whether by spray or by treated paper, plays an important role in the effectiveness of the treatments. Some leaf injury was caused by oil in the shredded paper. Consequently, some other means will have to be worked out for applying the growth regulators to the shredded paper before this method of application can find commercial acceptance.

Different forms of 2,4–D and of naphthaleneacetic acid or a 50-50 mixture of the two were equally effective in reducing leaf abscission.

The results were essentially the same whether the cauliflower was stored in the nailed crate or in the wire-bound crate.

Although there was some variation between tests it can be stated that throughout the two seasons the cauliflower generally remained in good salable condition for a storage period of 4 weeks. After about that long in storage there was progressive deterioration, as evidenced by wilting and yellowing of leaves and by spotting and decay of the curd. Inspections subsequent to those at 4 weeks were not made at uniform periods. For that and other reasons it would be difficult to state at what specific point stored cauliflower might be expected to become unsalable. This undoubtedly would vary from season to season and would probably depend upon such factors as quality and condition when stored, age of the field from which harvested, time of harvest, and many others. It would appear, however, from the results of two seasons' tests that Long Island cauliflower properly treated might reasonably be expected to hold up in storage at 33 degrees F for about 4 to 6 weeks. The use of

the growth regulators had no effect on such things as leaf wilting and yellowing or spotting and decay of leaves or of curd. By preventing leaf abscission the treatments do, however, have a pronounced effect in preserving the appearance of the cauliflower and in removing one of the chief obstacles to successful storage of Long Island cauliflower.

Summary

In storage tests conducted during 1947 and 1948 observations were made on 111 crates totaling 1280 heads of Long Island cauliflower. Leaf abscission during storage was practically prevented by the use of different forms of 2,4–D, naphthaleneacetic acid, or 50-50 mixtures of the two. These growth regulators were effective whether used as sprays or as vapors emanating from impregnated shredded paper. Some leaf injury resulted from the oil in the shredded paper. Treatments made at the time of harvest, either before or after packing, or made by spraying the plants in the field at the time of tying were about equally effective. Treated cauliflower held up well in storage (at 33 degrees F) for about 4 to 6 weeks, after which deterioration from leaf yellowing, and wilting, and from spotting and decay of leaves and curd made the cauliflower unsalable.

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Retarding Sprout Growth of Potato Tubers by Spraying the Foliage with 2,4,5–Trichlorophenoxyacetic Acid[1]

By J. Howard Ellison and Ora Smith, *Cornell University, Ithaca, N. Y.*

Previous papers (1,3,4) have dealt with the problem of retarding sprout growth of potato tubers by spraying growth regulating chemicals on the plants. The present paper is a report of the results obtained from a field experiment in 1947 and from other tests carried out in storage rooms during the winter of 1947–48.

Materials and Methods

In 1947 a field experiment was conducted on Bruce Cottrell's farm near Scott, New York in which aqueous sprays containing hormones were applied to an experimental area in a field of potatoes of the Sebago variety growing on a Howard gravelly loam soil. The field had been planted May 25, 1947 with 1500 pounds of 8–16–16 commercial fertilizer applied in bands at planting time. Regular cultivation was provided for the experimental plots throughout the growing season.

Treatments consisted of methyl ester of a-naphthaleneacetic acid (MENA) at 3000 ppm[2]; sodium a-naphthaleneacetate (sodium NA) at 500, 1750 and 3000 ppm; and sodium 2,4,5–trichlorophenoxyacetate (sodium 2,4,5–T) at 50, 175 and 300 ppm. The above chemicals were applied on August 1 (E), August 22 (M) and September 10 (L). Each plot received only one spray application so that it was treated either early, midseason or late. Sprays were applied at the rate of 150 gallons per acre through hand operated equipment. One untreated control plot was included in each replication, making a total of 22 treatments. A randomized block design was used with three replications. Each plot consisted of four rows 25 feet in length and only the inner two rows were sprayed and used for record.

After the plants matured and the vines were dead, the crop was harvested with a commercial two-row potato digger. The tubers were weighed during the grading operation so that yields could be recorded. Specific gravity of the U.S. No. 1 size tubers was taken as a criterion of starch content and table quality.

A 20-tuber sample from each of the field replicates (66 samples in all) was weighed and placed in storage at 50 degrees F on October 25, 1947 for sprouting and shrinkage measurements. On February 26, 1948 the samples were reweighed and desprouted. The weight of sprouts was obtained to the nearest gram.

On April 17, 1948 a storage test was begun using non-dormant

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[1]Paper No. 315, Dept. of Veg. Crops, Cornell University, Ithaca, N. Y. The authors are indebted to the Dow Chemical Company, Midland, Michigan and to the American Cyanamid Co., 30 Rockefeller Plaza, New York, N. Y. for contributing materials used in this study.

[2]MENA will not be discussed in the results since it gave essentially the same effects as sodium NA used at 3000 ppm.

Sebago potatoes. Treatments consisted of the isopropyl ester of 2,4,5–T at 0.5 and 1.0 gram and MENA at 1.0 gram per bushel. The chemicals were applied in the dust form to the potatoes, and untreated tubers were included for comparison. Treatment samples of 10 tubers each were placed in brown paper bags, replicated seven times, and stored at 50 degrees F until June 28, at which time the sprouts from each sample were removed and weighed to the nearest gram.

Results

Yield:—Yield data are not presented in this paper because none of the treatments altered yields relative to the control, which was 468 bushels of U.S. No. 1 size tubers per acre.

Specific Gravity:—Since specific gravity is correlated with tuber quality, it might be mentioned here that some of the hormone treatments reduced quality. As in the 1946 experiment (1), the injury was both external and internal, appearing similar to scab and hollow-heart respectively. In general, the earlier the treatments were applied to the plants the more severe was the injury to the crop. The higher rates of hormones were injurious, whereas some of the lesser concentrations were innocuous even at the early date of application. No ill effects were associated with the following treatments: sodium NA 500 or 1750 ppm used early, midseason or late; sodium NA 3000 ppm applied late; sodium 2,4,5–T 50 ppm applied early, midseason or late; or sodium 2,4,5–T 175 or 300 ppm applied late. All other treatments cause some injury to the crop and were deemed not practical.

To determine the statistical significance of the various treatment effects, the single degree of freedom technique as described by Snedecor (5) was used. This permitted grouping and weighting of treatments so that various comparisons could be made.

Table I contains the specific gravity data. The average specific gravity of the tubers from all the sodium NA treatments was not different from the control at odds of 19:1. However, the mean of 1750 and 3000 ppm sodium NA reduced the specific gravity relative to 500 ppm at 19:1 odds. No significance lay between 1750 and 3000 ppm.

The early sodium NA treatment reduced the specific gravity com-

TABLE I—Effect of Rate and Date of Application of Growth Regulators to Potato Plants on the Specific Gravity of the Tubers (Sebago Variety Planted May 25, 1947)

Growth Regulators	Rates (Ppm)	Dates of Application to Potato Plants			
		Aug 1 (Sp Gr)	Aug 22 (Sp Gr)	Sep 10 (Sp Gr)	Mean (Sp Gr)
Sodium naphthaleneacetate	500	1.064	1.064	1.068	1.065
	1,750	1.060	1.063	1.064	1.062
	3,000	1.058	1.062	1.061	1.060
	Mean	1.061	1.063	1.064	1.063
Sodium trichlorophenoxyacetate.....	50	1.063	1.065	1.066	1.065
	175	1.061	1.068	1.065	1.065
	300	1.058	1.063	1.064	1.062
	Mean	1.061	1.065	1.065	1.064
Untreated control 1.066					

pared to the mean of midseason and late applications at odds of 19:1, but no difference was associated with midseason versus late application. The average effect of the sodium 2,4,5–T treatments was no different from the control, but the early treatment reduced the specific gravity compared with the midseason and late applications. However, there were no other significant effects of 2,4,5–T on specific gravity.

The effects of foliar hormone sprays on the weight of sprouts of the tubers in subsequent storage is seen in Table II. The average of all sodium NA treatments did not affect sprout growth compared to the control, but the early sodium NA sprays did retard sprouting in comparison with the midseason and late treatments. The sodium 2,4,5–T reduced sprouting markedly compared to the sodium NA or to the control. Sodium 2,4,5–T at 50 ppm was less inhibitory than the mean of 175 and 300 ppm, but no difference fell between the latter two.

TABLE II—EFFECTS OF RATE AND DATE OF APPLICATION OF GROWTH REGULATORS TO POTATO PLANTS ON THE WEIGHT OF SPROUTS (GRAMS PER TUBER) IN SUBSEQUENT STORAGE AT 50 DEGREES F (SEBAGO VARIETY PLANTED MAY 25, 1947)

Growth Regulators	Rates (Ppm)	Dates of Application to Potato Plants			
		Aug 1 (Gm/Tuber)	Aug 22 (Gm/Tuber)	Sep 10 (Gm/Tuber)	Mean (Gm/Tuber)
Sodium naphthaleneacetate	500	2.30	3.07	3.22	2.86
	1,750	2.27	2.82	3.13	2.74
	3,000	2.27	3.13	3.10	2.83
	Mean	2.28	3.01	3.15	2.81
Sodium 2,4,5-trichlorophenoxyacetate	50	1.70	2.93	2.73	2.45
	175	1.22	2.25	2.75	2.07
	300	0.87	1.97	2.83	1.89
	Mean	1.26	2.38	2.77	2.14
Untreated control 3.17					

The most highly significant reduction in sprouting was effected by the early application of 2,4,5–T compared to the midseason and late treatments, with no difference showing between the latter two.

Storage Application of Sprout Inhibitors:—Table III shows the effects of applying the sprout retardants directly to the tubers in storage. Although the isopropyl ester of 2,4,5–T at ½ and 1 gram per bushel was highly effective in retarding sprout growth (see control), the MENA at 1 gram per bushel was still more inhibitory than an equal amount of the 2,4,5–T isopropyl ester.

TABLE III—EFFECT OF APPLYING HORMONES DIRECTLY TO SEBAGO POTATO TUBERS ON THEIR SPROUT GROWTH AT 50 DEGREES F (EACH VALUE IS THE MEAN OF SEVEN REPLICATES—70 TUBERS)

Chemicals	Rates (Gm/Bu)	Weight of Sprouts (Gm/Tuber)
Isopropyl ester of 2,4,5-T†	0.5	3.7*
Isopropyl ester of 2,4,5-T	1.0	2.9*
MENA‡	1.0	1.5**
Untreated control	None	10.8

*Significantly lower than untreated lots at odds of 99:1.
**Significantly lower than any other treatment at odds of 99:1.
†Isopropyl ester of 2,4,5-trichlorophenoxyacetic acid.
‡Methyl ester of a-naphthaleneacetic acid.

To obtain information on the inhibitory action of 2,4,5–T when its penetration into the tubers was assured, the following experiment was conducted. Ten toothpicks soaked for 1 week in a saturated solution of sodium 2,4,5–T were inserted about 1 inch into each tuber. Similar untreated tubers were used as controls. After storage for 3 months at 50 degrees F, treated tubers were just beginning to sprout, whereas several sprouts 3 to 4 inches long had developed on each of the untreated tubers (Fig. 1).

FIG. 1. Left: Tuber pierced with toothpicks which had been soaked in saturated aqueous solution of sodium 2,4,5–trichlorophenoxyacetate. Center: Same as on left except that picks were removed prior to photographing. Right: Untreated tuber.

The toothpick technique was further employed to insure equal penetration of sodium NA and sodium 2,4,5–T into comparable sets of potato tubers. Aqueous solutions of 1000 ppm of the two respective salts were used for soaking the toothpicks. One set of toothpicks was soaked in distilled water for comparative purposes. After the picks were soaked 5 days they were inserted into tubers of the Houma variety of similar size, and one series of untreated tubers with no toothpicks was included as a control. Eight replications were used.

Table IV shows very marked sprout retardation associated with sodium NA and sodium 2,4,5–T (see control), but no significant difference between the two chemicals. Toothpicks soaked in distilled

TABLE IV—SPROUTING OF HOUMA POTATOES AS AFFECTED BY PIERCING THE TUBERS WITH TOOTHPICKS WHICH HAD BEEN SOAKED IN HORMONES AND IN DISTILLED WATER (SINGLE TUBER PLOTS WERE USED AND EACH VALUE IS THE MEAN OF EIGHT TUBERS)

Treatments	No. Picks Per Tuber	No. Sprouts Per Tuber	Weight Sprouts Per Tuber (Gms)
Toothpicks soaked in sodium NA* (1000 ppm)	10	3.0	3.0
Toothpicks soaked in sodium 2,4,5-T† (1,000 ppm)	10	5.0	2.6
Toothpicks soaked in distilled water	10	12.1	9.2
Untreated control	None	11.4	11.0

*Sodium naphthaleneacetate.
†Sodium 2,4,5-trichlorophenoxyacetate.

water had no significant effect on number or weight of sprouts compared with the unpierced control tubers.

Discussion and Summary

Sodium 2,4,5-T sprayed on potato foliage at 50 ppm was more inhibitory to subsequent sprouting of the tubers than was 3000 ppm of sodium NA. Both chemicals were much more effective in reducing sprout growth when sprayed on the plants just prior to blossoming (early) than when applied later in the season. Early application of sodium 2,4,5-T at 175 and 300 ppm or sodium NA at 1750 and 3000 ppm produced injury to the crop, but 50 ppm of the 2,4,5-T applied early did not harm the tubers and gave significant sprout inhibition. Sodium NA at 500 ppm (early) was harmless, but not inhibitory to sprouting.

Isopropyl ester of 2,4,5-T was not quite as inhibitory to sprouting as was MENA when both were applied in the dust form to potatoes in storage. The fact that the isopropyl ester is slightly less volatile than the methyl ester may constitute a handicap for the 2,4,5-T for it has been established that these materials act in the volatile form (2).

Matched tubers which had been pierced with toothpicks impregnated with sodium NA and sodium 2,4,5-T respectively failed to show any significant difference in number or weight of sprouts.

Why these two chemicals differed so widely in their inhibitory power when used as foliar sprays, but differed so little when used directly on tubers in storage cannot as yet be explained. Further work is being carried on involving these and other sprout inhibitors.

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Vegetable Varieties for the Tropics[1]

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THE importance of the proper choice of vegetable varieties for any given area is well known. In view of the relative paucity of information regarding vegetable varieties suited for the Tropics the results of our investigations are given here.

Raising temperate-climate vegetables in the Tropics often is difficult because of the prevalence of plant diseases, insect pests, and the high temperature. In areas that are too warm, head lettuce and cauliflower, for example, may fail to form heads while tomatoes may chiefly produce such small fruit as to be unmarketable. This is often not due, as may generally be thought, to high temperatures prevalent during the day, but to high night temperatures (1, 2, 3, 4). It appears that in areas where the night temperature does not drop below 77 degrees F it is impossible to obtain a good crop from most tomato varieties which are in ordinary commercial use in temperate regions. However, there is great variation among vegetable varieties in their ability to produce crops under conditions of high temperature, and much can be done towards obtaining good yields merely through the proper varietal choice.

This paper is the result of 2½ years of practical experience at Curacao, in the Netherlands West Indies. Curacao is a small island in the Caribbean located at approximately 12° N latitude. It has an average annual rainfall of about 25 inches which falls mainly during a long rainy season in the fall and early winter. Despite the low annual rainfall the relative humidity is quite high, being an average of about 74 throughout the year. The temperature is quite moderate and fairly even. The highest recorded temperature for the past eight years was 96.4 degrees F, while the lowest was 64.5 degrees F. Table I giving certain climatological data that include the average diurnal temperature range by months is included. The minimum temperatures are to be noted particularly. The average minimum temperature even during the winter months is in the 70's. During the summer the average minimum temperature, usually occurring at night, does not drop below 77 degrees F.

At Curacao the Shell Oil Company maintains a sizeable hydroponics unit in order to produce fresh vegetables for its employees. A large number of the usual temperate-climate vegetables were grown.

Because of the desirability of placing this project on a self-supporting basis four main factors were considered in this program with relation to each crop: 1, amount of labor involved; 2, total yield; 3, length of time a crop occupied a bed; and 4, market price. Certain crops which grew well, such as tendergreen mustard and shogoin turnip were discarded in favor of swiss chard, because the latter could be produced more cheaply.

[1]This work was done from 1944 to 1946 while the authors were employed by the Curacaosche Petroleum Industrie Maatschappij (Shell Oil Co.) at Curacao, Netherlands West Indies. Thanks are due the management of C.P.I.M., Director A. Troost in particular, for permission to publish these results.

TABLE I—CLIMATOLOGICAL DATA* FOR CURACAO, NETHERLANDS WEST INDIES

	Temperature			Average Temperature	Average Maximum Temperature	Average Minimum Temperature	Average Relative Humidity	Cloudiness**	Rainfall (Inches)
	8 A M	1 P M	6 P M						
January	78.0	83.0	78.0	79.0	86	73	75.3	4.95	3.02
February	78.0	83.0	78.0	80.0	86	73	72.7	4.64	0.88
March	78.0	84.0	78.0	80.0	87	73	73.0	4.63	0.72
April	80.0	85.0	79.0	81.0	88	75	74.1	4.63	0.39
May	81.0	87.0	81.0	83.0	89	76	74.7	4.68	0.49
June	81.0	87.0	81.0	84.0	89	77	74.0	4.55	1.06
July	80.0	87.0	81.0	83.0	89	77	73.3	4.22	1.12
August	83.0	88.0	82.0	84.0	89	77	71.6	3.95	1.39
September	83.0	89.0	83.0	85.0	92	78	71.6	4.23	2.17
October	82.0	87.0	82.0	84.0	89	78	73.9	4.92	3.45
November	77.0	85.0	81.0	83.0	89	75	78.0	5.37	6.11
December	82.0	84.0	79.0	81.0	87	75	77.0	5.04	4.46
Yearly average	80.2	85.7	80.2	82.25	88	76	74.1	4.63	25.26

*This table based on the records for eight years (1937 to 1944).
** 0 = Sky cloudless.
10 = Sky completely overcast.

Plants were all grown in the full sun except where it is noted that shade was given. Nutrients were supplied to the plants by means of subirrigation of the gravel beds in which they were growing. Although the salinity of the water was higher than desirable for optimum growth yet otherwise excellent growing conditions were provided. While the results obtained were from plants grown by means of gravel culture, yet they are believed to be of the same relative order that would have been obtained if the plants had been grown in soil. For reasons of brevity the yield data are not included.

The various vegetables tested may be divided into three groups:

A. Crops extensively tested (that is, recommended varieties which were given from 6 to 12 trials): tomatoes, cucumbers, swiss chard, lettuce, celery.

B. Vegetables moderately tested (3 to 6 trials): eggplant, shogoin turnip, tendergreen mustard, green beans.

C. Vegetables given preliminary testing (1 to 3 trials): peppers, various cooking greens except those listed above, lima beans, butter beans, cauliflower, beets, carrots, radishes, leeks, broccoli.

TOMATOES

Sixty-three varieties of tomatoes were tried. These were: Beefheart, Beefsteak, Bide's Recruit, Bison, Bonny Best, Bounty, Break of Day, Burbank, Cardinal, Cleo, Comet, Cuban Marglobe, Earliana, Early Baltimore, Early Santa Clara, Firesteel, Fletcher's Special, Gloriana, Greater Baltimore, Grothen's Red Globe, Gulf State Market, Hundredfold, Indiana Baltimore, Italian Plum, John Baer, Jubilee, Livingston's Globe, Lloyd's Forcing, Long Calyx, Louisiana Pink, Master Marglobe, Marglobe, Matchless, Michigan State Forcing, Mildglobe, New Globe, Norton, Oxheart, Pan American, Pearson, Pennheart, Ponderosa, Pritchard, Prodigious, Red Pear, Red Rock, Richmeat, Rutgers, Santa Clara, Scarlet Dawn, Scarlet Globe, Stokesdale, Stumpp and Walter's Best of All, S. & W.'s Climber, Summerset, Tabletalk, The

Fruit, The Orange, Urbana Forcing, Valiant, Victor, Waltham Forcing, and Winsall.

Most of these tomato varieties were tried once during the winter and once during the summer; the 20 most productive varieties were then planted at least four successive times, each planting containing at least 125 plants. Seedlings were transplanted into the beds when 3 weeks old and the plants could be counted upon to begin their yield within 2½ months from seeding.

Although, as can be seen from the chart, the actual temperature differences between the summer and winter months are relatively slight, yet there was found to be a decided difference in fruit production in these two seasons among the ordinary commercial varieties.

Tomatoes may be divided into two general groups—determinate and indeterminate. The latter varieties under favorable conditions may be made to yield over a long period of time, and constitute the main body of commercial varieties. Even in Curacao during the winter they produced fine, large fruit, and some varieties could be depended upon to yield well over 10 pounds per plant. But in the summer, fruits produced by plants in this group were small and few in number. The determinate varieties, on the other hand, were found to set fruit well during the summer. Actually, they yielded as well as did the other type during the cooler season, but on the whole did not continue over as long a bearing period.

The following varieties proved to be the best from among those tried, and are listed in the order of their total yield: during the hot season — Firesteel, Bounty, Pritchard, Pearson, Victor; during the cooler season — Michigan State Forcing, Richmeat, Indiana Baltimore, Marglobe. Richmeat produces large but relatively few tomatoes which have a tendency toward being misshapen. For marketing, it is better to use either Michigan State Forcing or Indiana Baltimore.

Cucumbers

Thirty-eight varieties, including most of the standard ones listed in the commercial catalogs, were tried. They were as follows: A and C, Black Diamond, Burpee's Hybrid, China, Clark's Special, Colorado (syn. Submarine), Cubit, Curacao (a strain grown on the Island for many years), Davis Perfect, Deltus, Double Yield, Early Fortune, Early Green Cluster, Early Green Market, Everbearing, Forcing White Spine, Fordhook Famous, Improved Long Green, Irondequoit, Longfellow, Mandarin, Marketer, Mincu, National Pickling, Oriental Climber, Perfection, Prolific White Spine, Puerto Rico 39 (obtained from the Puerto Rico Experiment Station), Shamrock, Staysgreen Long Type, Straight 8, Sunnybrook, Surinam (obtained from Dutch Guiana), The Henderson, The Vaughan, Wauchula Staysgreen, White Spine, and Woodruff's Hybrid.

The plants were seeded directly in their permanent locations and were supported upright by strong twine. The ends of side shoots beyond the female blossoms were pinched off. It was found that plants given full sun produced considerably more fruit than those grown under shade.

Cucumbers are readily grown in warm areas, and do not present the seasonal problems which tomatoes do.

The variety which was found to far outyield all others tried was Mandarin. It is very early and a strong grower and produces quantities of large high-quality fruits. The first fruits are ready in about 43 days and the vines are producing heavily a week or 10 days later.

Two other good varieties are Shamrock and Puerto Rico No. 39. The former is mosaic-resistant and makes a vigorous growth. It is not as early as Mandarin and produces a shorter, stockier fruit which is fine in quality. The Puerto Rico variety, seed of which were obtained from the Puerto Rico Experiment Station, is almost as early as Mandarin and produces many small fruits. No other variety approached the yield of any of these three, while Mandarin easily topped the list.

Eggplants

Eggplants grew quite well as might be expected since they are a warm weather crop, though they were subject to infestations of a sucking insect which was very hard to control. The following varieties were tested: Black Beauty, Early Beauty, Florida Special, Fort Meyers Market, New Hampshire Hybrid, Rosita (a light colored one, seeds of which were obtained from the Puerto Rico Experiment Station), and Purple Thornless.

Purple Thornless proved to be by far the best of those tried, producing its large fruits as early as those of Early Beauty. Black Beauty and Early Beauty are also recommended.

Peppers

Extensive trials of peppers were not made. Only three varieties (California Wonder, Ruby Giant, and Florida Giant) were tried and proved to be of value in the order named. California Wonder produced large, meaty fruits from the same plants over a period of five months and could have continued bearing but were removed to make way for other plantings.

Swiss Chard

Eight varieties of chard were tried: Cut and Come Again, Dark Green White Rib, Fordhook Giant, Green Plume, Lucullus, Rhubarb, Spinach Beet, and White Silver. Fordhook Giant, Lucullus, and Rhubarb chard are savoyed types while the others are smooth-leaved.

Swiss chard was found to far outyield any other greens which were tried. In one trial, a bed was occupied by the same planting of chard for 11 months and was yielding heavily for 9 months of that time. It was cut over every week to 10 days. The best yielder in that trial, Lucullus, produced 524 pounds from a space 3 feet by 20 feet.

Except for Rhubarb chard, which did poorly, all varieties did well, though Green Plume, Lucullus, Dark Green White Rib, and Cut and Come Again produced better yields than did the others. It will be noted that these are all smooth-leaved. Insecticides were found to be far more effective on the smooth than on the savoyed types. This might have been the reason for their outyielding the savoyed types.

Other Cooking Greens

The following cooking greens besides swiss chard were tried: endive, chinese cabbage, collards, kale, tampala, spinach, rapegreens, mustard, and turnips. All were grown under light shade.

Three varieties of endive were grown: Batavian Full Heart, Florida Deep Heart, and Green Curled. All grew rapidly and were remarkably healthy. The Green Curled produced the largest and most attractive plants. There was little difference between the other two in yield.

Of the chinese cabbage, the varieties tried were: Wong Bok, Pe Tsai, and Chihli. Wong Bok produced the heaviest plants, though Chihli was the more satisfactory in the rainy season as the plants were not as subject to rotting as were the other two. It is not known whether they would form heads if allowed to mature; they were planted at the beginning of the rainy season, and when the plants showed tendencies towards rotting they were pulled out. In addition, they were greatly subject to attacks by leaf chewing insects and aphids and for these reasons further experimentation was discontinued.

Collards, both Cabbage and Southern, proved to be too slow-growing to be commercially profitable, taking 51 days to come to the point where they could be sold. Other greens, as mentioned later, were ready for sale in considerably less time. Kale, tampala and spinach varieties were found to do poorly and were discarded.

Rape greens grew rapidly and produced heavily but were not as desirable for selling as other greens which had larger leaf blades.

Five varieties of mustard were grown: Tendergreen, Chinese Broadleaf (obtained from Hawaii), Florida Broadleaf, Southern Giant Curled, and Improved Ostrich Plume. The last two were the least vigorous of all, while Tendergreen far surpassed all the rest, being of saleable size in about 27 days, though it was found to be more profitable not to harvest until 35 or 37 days.

Seven-top and Shogoin were the two turnip varieties tested. The former grew well but Shogoin produced almost double its yield.

Of all the greens tried, with the exception of Swiss Chard, Shogoin turnip and Tendergreen mustard produced the greatest yields and could be counted on to produce heavily within 37 days.

Lettuce

Twenty lettuce varieties were tried. They were: Bibb, Black Seeded Simpson, Butternut, California Cream Butter, Cornell 456, Cosbia, Cosberg, Grand Rapids, Grand Rapids U. S. No. 1, Great Lakes, Hanson, Iceberg 44, Manoa (obtained from Hawaii) Mignonette, New York (syn. Los Angeles and Wonderful), New York P. W. 55, Oak Leaf, Slobolt, Wayahead and White Boston.

Excellent leaf lettuce could be raised in Curacao but no head lettuce was produced. Even Mignonette and Manoa failed to head during the cool season. In Trinidad, however, where the night temperatures are a bit lower, excellent heads from Mignonette could be had. The closest approximation to a head was produced by Bibb, which developed a small compact plant with the center leaves tightly folded. Its quality was superior, but it remained at its prime only for a comparatively

short time. Oak Leaf, Black-Seeded Simpson, and Slobolt are recommended varieties of leaf lettuce.

Successive harvestings of the lower leaves may be made, and this can be a profitable crop provided labor is not too expensive and the distance from market not too great.

Lima Beans and Butter Beans

Limited trials of lima beans and butter beans were made. Only pole limas were tried, as the bush type does not produce enough for the space it occupies. Varieties tried were: Burpee's Giant Podded, Carolina or Sieva, Improved Challenger, King of the Garden. Of these, Giant Podded and King of the Garden were the most prolific. Butter beans were found to be even easier than lima beans to grow. Old Florida Pole was the most satisfactory of this type.

Green Beans

While not as much work was done with green beans as with tomatoes and lettuce yet a number of trials were made. Cowpeas and lima beans can be more readily grown than green beans in hot areas, although the latter can be made to produce a good crop, particularly if they are planted at the beginning of the cooler season. Varieties tried were: Blue Lake, Burger's Stringless, Ideal Market, Kentucky Wonder, Kentucky Wonder Rust Resistant, King Horticultural, McCaslan, Potomac, Scotia, St. Louis Perfection, St. Louis White Cornfield, and White Creaseback. Of these, Kentucky Wonder Rust Resistant was by far the best yielder. Others recommended are Kentucky Wonder and Potomac.

When grown under conditions of subirrigation in the tropics green beans tend to rot readily, especially when newly planted, and must be treated with the utmost care.

Celery

Varieties of celery tested were: Easy Blanching, Giant Pascal, Golden Self-Blanching, Green Florida Pascal, Kilgore's Improved Pride, Masterpiece, Prizeheart, Smallage, Utah, and White Plume. As might be expected it was found impossible to produce fine quality table celery during the warmer season. However, celery to be used for cooking can easily be grown throughout the year. Individual outer leaves may be harvested continuously, thus making this a long-lasting crop. After several months of harvesting, the stalks tended to become bitter. In the cooler season the variety Green Florida Pascal produced a good quality of table celery, although it did not produce the very large stalks that it does when grown in cooler regions.

For cooking Smallage was by far the best variety as it was highly resistant to diseases.

Cauliflower

Even when planted during the cool season, none of the usual commercial varieties of cauliflower such as Super Snowball, Snowdrift and White Mountain produced heads. However, fine success was had with

seeds obtained from Sutton's in India. Early Patna, Early Market and Maincrop Benares were tried. The latter produced the largest heads but was 2 weeks later. Early Market was far superior in total yield to either of the other two. Heads were of excellent quality and good size. Because of the long time to bring a crop to maturity extensive testing was not carried out.

Miscellaneous Crops

Beets, carrots, and radishes can all be grown, particularly during the cool season, but only some preliminary trials were made. Results indicated the following varieties to be good, although only a few varieties were tested. Beets: Detroit Dark Red and Crosby's Egyptian. Carrots: Nantes Half Long, and Chantenay. Radishes: Early Scarlet Globe, Saxa, and Icicle, the latter being better than the other two.

Italian Green Sprouting Broccoli gave good results in the cooler season. Two varieties of leeks were tried with excellent results: American Flag and Elephant; the former was the better yielder.

Discussion

In general, whenever confronted with a choice of varieties which appeared to have equal qualifications, it was found that the earlier yielding one was better. It was also preferable to choose a smooth-leaved plant rather than a savoyed one, and to choose a more upright growing variety than one which tend to sprawl. The reason for this is that it is easier to apply insecticides and fungicides to control plant diseases and insects. For the same reason, where insects and diseases are prevalent, it is often well worth the additional cost of staking plants rather than to allow them to sprawl on the ground. In humid regions where leaf diseases are apt to be severe it is suggested that the earlier yielding determinate tomato varieties be planted exclusively and pulled out after the yield begins to decrease sharply. It should be stated that despite the fairly high relative humidity, few leaf diseases were encountered in the present work and they were no problem. During the hot season with some crops, for example, swiss chard, we were occasionally bothered with the damping-off and rotting of young seedlings. Measures for its prevention and control were developed. However, the insects abounded and some were difficult to control. This was particularly true as most of the newer insecticides developed during the war were not available.

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Balanced Programs for Southern Horticulture[1]

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If I were asked to express my version of the philosophy of the American people in a short, concise statement, I would put this statement in the form of a question. Is there a better way? Can we make a better gadget, or a more efficient piece of machinery, or develop a new process? In our own work, can we develop a superior plant, or work out a new practice, or improve an old practice? As a result of the intense desire of the American people to find the better way, a large number of organizations and institutions have developed which are characteristic of the American way of life. One of these organizations is the land-grant college system of the United States. As members of the land-grant college system, it is proper and fitting that we pause in our labors, as occasion requires, to examine our methods, techniques and procedures in order that we may find the better way. I think we can find a better way by the development and implementation of more balanced programs in research, in teaching and in extension.

Balanced Programs in Research

In solving the production problems of any crop both the environmental and hereditary factors should be considered in combination.

The behavior of an organism is due to its genes and the influence of the environment on the genes. In other words, two great groups of factors are involved: hereditary factors and environmental factors. Thus, in the solution of production problems both the hereditary and the environmental factors should be considered. Since the establishment of the United States Vegetable Breeding Laboratory at Charleston, South Carolina, there has been a marked increase in the breeding of vegetable crops for adaptation to southern conditions. However, numerous investigations have shown that the environment markedly influences the expression of the genes. As the review of Yarnell (24) shows, numerous genes under one set of conditions express themselves in one direction, and the same genes under another set of conditions express themselves in another direction. Since the environment markedly influences the expression of the genes, an analysis of the southern environment in relation to adaptation would seem to be in order. What is the nature of this southern environment? Can this environment be improved or made more favorable or must the environment be accepted as it is and crops bred for adaptation accordingly?

As you know, the principal factors of the environment are temperature, light, water and nutrients. In general, temperature and light levels are sufficiently high to permit photosynthesis to take place most,

[1]Address of the retiring chairman of the tenth annual meeting of the Southern Region of the American Society for Horticultural Science, Louisiana State University, Baton Rouge, La. January 31, February 1, 2, 1949. Published with the approval of the Director of the Mississippi Experiment Station as Journal Article 198 (n.s.).

if not all, of the year. This is manifested by the all year grazing programs that are being developed; by the growing of cool season vegetable and flower crops in the fall, winter and early spring; by the growing of warm season vegetable and flower crops in the spring, summer and fall; and by producing a wide variety of deciduous and evergreen tree fruits throughout the region. However, despite the fact that temperature and light levels are favorable for photosynthesis, yields of many crops are low.

What is the situation with the water supply? The records (5) show that the natural water supply in the humid South is adequate. However, as you know, crops in this region frequently suffer from lack of water. Every year in some district there is a period of drought. This period may exist for one or two weeks only, yet it may come at a time when crops need rain badly. A recent report shows that in the humid section of the country there were one hundred twenty-seven droughts from 1919 to 1939; this is an average of six droughts per year. These droughts varied in length from 10 to 53 days. Another report (9) shows that 41.5 per cent of the two hundred twenty-six days frost-free growing period at State College, Mississippi, from 1910 to 1947, a period of 38 years, had insufficient rain. As is well known, droughts induce water deficits within the plant. This in turn lowers the rate of photosynthesis. This in turn decreases yield and quality and upsets the normal marketing period of the crop. Since the rainfall is adequate, and since the grower is entitled to receive dividends on his investment in land, seed, fertilizer and so forth, the rain should be stored when not needed and applied when needed. Thus, comprehensive investigations of supplementary irrigation seem to be in order. These investigations require a working knowledge of the morphology and physiology of the crop in question, of the physical and chemical characteristics of the soil, and of the economics of irrigation systems. Here is an excellent opportunity for the horticulturist and the irrigation engineer to work together in the solution of these irrigation and water control problems. In the October issue of *Better Crops with Plant Food* there is an announcement of the formation of a committee called the National Soil and Fertilizer Research Committee. The purpose of this committee is to assist in planning national and regional studies of soils, fertilizers, and irrigation. Would not it be well for the Southern Region of the Society to consider the formation of a committee to contact and work with this committee to promote irrigation studies with horticultural crops throughout the region?

What is the situation with the nutrient supply? As you know, most soils of the humid South are strongly leached, highly acid, and low in nutrients (20). However, they can be made more fertile. The growing of a crop at all times on a given soil will reduce leaching to a minimum; the application of dolomitic limestone will reduce acidity and provide the necessary calcium and magnesium; and the application of commercial fertilizers will increase the nutrient content. Tiedjens (21) believes that the conditioning of the topsoil and the subsoil in combination is the real secret to high yields. The amelioration of the subsoil either by liming or by subsoiling or both will permit the development

of deep root systems. In this way, the tops will be supplied with adequate water, photosynthesis will proceed unabated and yields and quality will be high. Large supplies of available water are necessary during periods of high transpiration in order to maintain a high rate of photosynthesis. Maximov (14), Magness (13) and others have shown that a high rate of transpiration, a high rate of photosynthesis, and deep root systems go hand in hand. Although growers of tree fruits are familiar with and at times are concerned with the nature of the subsoil, its importance in vegetable and flower crop production seems to have been badly neglected and overlooked.

Recently, Andrews and his associates (2) have secured remarkable results in the use of anhydrous and aqueous ammonia in the fertilization of cotton, corn and small grains. Although the work was started only three years ago (1944), over 500,000 acres of cotton and corn were ammoniated with these materials in 1948. Anhydrous and aqueous ammonia have certain advantages. They are retained by soil colloids, and they cost less per pound than other nitrogen carriers. Satisfactory machines for their application have been developed. Despite the rapid acceptance of anhydrous and aqueous ammonia by cotton and corn farmers, only limited experiments with these materials are under way with horticultural crops — with sweetpotatoes and peppers at State College, Mississippi, with tomatoes, cabbage, and snap beans at Crystal Springs, Mississippi, and with tung at Bogalusa, Louisiana. Growers of horticultural crops use large quantities of nitrogen. Thus, the use of these new forms should be investigated, particularly from the standpoint of maintaining a balance between vigorous growth and fruit production. Murneek (15) has shown the close relation of vigor of growth and fruit production in the tomato and that the nutrient requirements of the fruit are satisfied first. More recently Lachman (11) has shown that blossom removal prolongs vigor and productivity. This is a way of diverting the nutrient supply from the fruit to the foliage. Present day varieties undoubtedly exhaust the available nitrogen supply for fruit production. As a result, there is very little left for stem and leaf production and the plant dies. Investigations are needed to determine whether applications of these new forms may maintain a balance between vegetative growth on the one hand and fruit production on the other. Their use would seem to be particularly applicable to crops with the indeterminate type of growth.

Another development which deserves more consideration is the chemical control of weeds. Weeds markedly decrease yields. They use carbon dioxide, light, water and nutrients which would otherwise be used by the crop. There is only so much of these materials to go around. According to Hildebrand (8) the United States Chamber of Commerce estimated that weeds cause farmers and gardeners of the United States an annual loss of three billion dollars. If weeds were successfully controlled by chemicals, not only would this tremendous loss be avoided, but also possibilities for high yields per acre would become apparent. Smith (19) has pointed out that plants are grown in rows to provide space for cultivation in weed control. With chemical weed control this space might be more fully utilized. The plants could be set

much closer. This in turn would necessitate high fertilization, applications of irrigation water, strict sanitation, the application of insecticides and fungicides by heliocopter or plane and the use of adapted varieties. In this way, the productive capacity of the land would be increased by two or three fold. Because the successful use of chemicals in weed control may practically revolutionize growers' practices, investigations with these materials should be pushed vigorously.

The use of adapted varieties and the concomitant improvement of the environment is nothing new. Two striking examples within the Southern regions are the recent research work with field corn and the development of year round grazing programs. As late as three years ago many corn scientists believed that the maximum yield that could be expected in the South was about 35 bushels per acre, and many pasture specialists believed that the development of year round grazing programs was impracticable. At present 100 bushel corn clubs are springing up all over the South, and year round grazing programs are being established in many dairy and livestock sections. In each case, both the hereditary and environmental factors are considered in combination. Why not follow the same procedure in our own work? This is particularly necessary in the testing of new varieties in order that they will have an opportunity to show their potentialities to the fullest. The data of the paper by Ware and Johnson (22) presented at this meeting and the data cited by Shaw (18) indicate that the use of adapted varieties, relatively large amounts of commercial fertilizers, organic matter and supplementary irrigation in combination will markedly increase the yields of truck crops grown in the region.

Balanced Programs in Teaching

The training of research workers, teachers and extension workers in horticulture is just as important in contribution to the science of horticulture as the development of a new variety or a new process or a new cultural practice.

As you know, our work in teaching consists in training three rather distinct groups: (a) the non-majors — students who major in fields other than horticulture; (b) the majors — students who specialize in some specific or general field of horticulture; and (c) the graduates. Since certain institutions within the southern regions are planning to extend their graduate programs, I shall confine my remarks entirely to the subject of training the graduates. In accordance with the trends and needs of the times, graduates should be trained in independent research, in cooperative research, in teaching and in certain aspects of administration. In the past and for the most part at present, graduate work consists primarily in training for independent research. Bradford in his presidential address at the Dallas meeting in 1941 (4) traced the development of graduate training in horticulture in the land-grant college system. He states, "The graduate student who wishes a degree, whatever his purpose, must still demonstrate his ability to conduct independent research". In other words, the emphasis has been largely on training for independent research. Very little attention has been given over to training in cooperative research, to training for effective teach-

ing and to training for efficient administration. There is a great need for balance in all four types of training. At least, it seems that there should be less emphasis on independent research and more emphasis on training for cooperative research, teaching, extension and administration.

About five years ago a colleague stated that in his opinion research was largely an individual proposition. The question immediately arises, are we conditioned for cooperative work? Cannot our graduates, with adequate training, be just as effective and successful in cooperative research as we have been in independent research? As you know, more research is being done on a cooperative basis. Many present day problems are rather complex and require the application of many sciences for their solution. As a result, many workers are banding together as research teams. Notable examples within the southern regions are the Southern Cooperative Group, the Southern Sweetpotato Research Program, the Southern Vegetable Crop Variety Trials, the Southern Small Fruit Research Group, and more recently the Southern Ornamental Horticulture Group. From past experience we have acquired sufficient information which will serve as a basis for formal training. Certainly, the graduate student should be trained in the necessity and desirability of caring for a set of plots of a cooperative project as he would care for a set of plots of his individual projects. Certainly, he should be trained in the necessity of following uniform techniques and procedures in order that the data may be pooled, if necessary, and remain on a comparable basis.

Whether the graduate thesis should be developed independently or jointly with two or more students should be optional with the students concerned. However, as Adams (1) has pointed out, any individual student should never be placed in a subordinate position and made to do a large amount of routine work. Care should be taken to develop initiative and resourcefulness and to maintain independence of thought. In a favorable environment and with proper facilities, the development of students working together as teams should be highly satisfactory. Let us remember that a classic in horticulture literature was developed by two men working together. I refer to Kraus and Kraybill in their work on vegetation and reproduction with special reference to the tomato (10).

The training of teachers and extension workers in horticulture requires training primarily in teaching and extension problems. Training in independent research does not necessarily make for more effective teaching or extension. In fact, it may do just the opposite. The graduate trainee should become more proficient in the tools of his particular field. Bradford (4) suggests that effective teachers can be trained by developing scholarship. He points out that the very high productivity of research has created a new problem — the necessity for digesting, assimilating, evaluating and collating the results of research of a given field. In other words, the training of teachers means the development of scholars. This type of training would be of inestimable value to investigators and administrators. The investigator would have more time for actual research and the administrator could more effectively evalu-

ate proposed research projects. Bradford (4) states, "Let us remember that Darwin accomplished as much or more by putting together scattered bits of information brought forth by others than he did by his investigations". Despite Bradford's admonition, there is very little in our graduate curricula to develop the Darwins of the present and the future, even though the need is far greater now than it was in Darwin's time.

There is also a great need to develop more effective methods of teaching and extension work. As Anderson has pointed out (2), in the past the society has placed much emphasis on the "know-how" of effective independent research. Are we placing sufficient emphasis on the "know-how" of effective teaching and extension? The fundamental facts of the science of horticulture have accumulated in sufficient quantity to place the teaching of the subject on a comparatively firm foundation. Our problem is how best to present the facts to the student and to the grower. This does not mean that we should turn to specialists in educational methods. We, as individuals and as a group, are capable of developing our own methods peculiar to the nature of our own material and to our own problems. The fact that the Southern Region of the Society has recently initiated a series of programs on teaching and extension problems is most encouraging.

Sooner or later the research worker, the teacher and the extension specialist finds that some or all of his duties are administrative in nature. Some workers become deans and directors — positions which are wholly administrative, and others become heads of departments, directors of research laboratories, superintendents of branch stations, leaders of local or regional research projects, part-time student counselors and so forth — positions which require a certain amount of administrative work. Since effective administration is not inherent in mankind, the graduate student should receive training in administration. This training would seem to logically fall into the following two categories: (a) the presentation of certain self-evident truths; and (b) a discussion of the characteristics of effective administration. These self-evident truths should become part and parcel of the individual. These are: (a) The graduate student is primarily training himself to become a public servant. This training is wholly or partially at public expense. Thus the worker has certain obligations to meet. He should be impressed with the fact that he is hired to do a specific job, to do it well, effectively and efficiently. (b) His salary comes from taxes. Whether the check comes directly from the United States treasury or from some state bank, it comes from the same source — the tax payer. In other words, regardless of whether we are a member of a Federal or State organization, we are all in the same boat, we all have the same function, we are all interdependent. (c) The data the student obtains or the work that he does transcends his own importance. Thus, in the selection of graduate students not only should his scholastic attainments be considered but also his attitude toward his fellowmen. Clearly, the person who is primarily interested in the welfare of others will be more happy in this type of work than the person who is primarily interested in the promotion of his own interest and aggrandizement.

What are the characteristics of effective administration? An effective administrator does three things: (a) he picks good men; (b) gives them the necessary authority to meet their responsibilities; and (c) keeps other people off their necks. In other words, the administrator creates a favorable environment for effective and efficient work. He allocates funds to provide for the necessary facilities in the laboratory, the greenhouse and the field, and for the necessary secondary or technical assistance, and he avoids overloading the members of his staff. Too often the investigator or teacher with training equal to that of an M. D. must do the work that an intelligent high school graduate could do equally well. I refer to the running of analysis of variance, the running of routine bio-chemical and biophysical determinations or the raising of plants in preparation for laboratory work in the teaching of horticulture courses. Too often the research worker has more projects, the teacher has more courses and students and the extension worker has more enterprises than he can handle with dispatch and efficiency. No wonder many research projects drag out from one year to the next; no wonder the teacher continues to use the same lecture notes from one year to the next; no wonder the extension worker never or seldom establishes a given enterprise. The research worker needs time for creative thinking; the teacher needs time to maintain scholarship; the extension worker needs time to firmly establish a given enterprise. Here again, as in the case of cooperative research, we as a group have acquired sufficient experience which would serve as a basis for the training in the necessary administrative work. At least one course or part of a course should be given over to this important phase of our activities.

Balanced Programs in Extension

The demonstration is an effective method of extension.

As you know, the Extension Service was established in 1914. Its function is to disseminate the results of research. Just how best can this function be attained? Various methods are used: talks, lectures, publications of various kinds and demonstrations. It seems that methods by which the grower can see the actual results of research are particularly effective. Let me cite three examples. About 15 years ago the cantaloupe industry in southwestern Michigan was in serious difficulties (6). Yields and quality were low, prices were low. Growers appealed to the Experiment Station for help. Accordingly, a brief yet effective survey was made to determine the pertinent problems and experiments were started to find their solution. The tests were conducted in cooperation with growers — right in the growers' fields. A graduate student was assigned to the project. He applied the treatments, recorded the data, visited the growers, and the growers visited him. In fact, visits of growers were encouraged and at appropriate times field days were conducted. There was little need to point out the best strain or variety, the most effective fertilizer treatment or pest control program. The growers came, they saw, they were convinced, and they adopted the outstanding treatment the following year. In other words, the growers accepted the results and recommendations as fast as they

were obtained and formulated. In fact, the growers were following recommended practices long before the results were actually published.

As you know, with the exception of fundamental studies, conducted at Beltsville, Maryland, the research work in tung is carried out in four field laboratories. A unique feature of this program is that all of the work is cooperative either with state experiment stations or with private tung growers. As Potter has pointed out (16) this arrangement is not without disadvantages, yet the advantages seem to outweigh the disadvantages. A marked advantage is the wide distribution of the experiments and the rapid acceptance of the results by growers.

Recently, the Alabama station established production unit test farms. In general, these farms are given over to the operation of specific enterprises — cattle, hogs, dairy, truck crops are examples. The object is to produce high marketable yields at the lowest possible cost and to demonstrate the technique and "know-how" of specific industries. Data are recorded on yields, prices and costs. The plots are simply yet effectively labeled and wide publicity is given over to the work. According to Funchess (7), these units are attracting more attention than any other activity of the Alabama station. He states that more than 28,000 in organized groups visited the unit farms in 1947. The growers come, they see for themselves, they go home convinced.

Many states in the southern regions have established extensive branch station systems. For the most part, these stations have been located in a specific soils area. Their main purpose is to serve the growers in the immediate vicinity. The demonstration type of research would seem to be particularly applicable to this type of station. The tests could be run on the same soil and in the same climate of the locality which the station serves, and because of the proximity of growers to the station, they could attend in large numbers and at frequent intervals.

Summary

The South has been called Economic Problem Number 1 on the one hand (17) and Economic Opportunity Number 1 on the other. Whether we think in terms of liabilities or potentialities depends on the point of view. At present, many people are thinking more in terms of the potentialities rather than the liabilities. For example, Robert E. Wood (23), chairman of the board of Sears Roebuck and Company, states that two potentially rich areas await development: the Pacific Coast and the one thousand mile sweep from Pensacola, Florida, to Brownville, Texas. He states, "Within a two hundred mile radius of Houston, Texas, more wealth is taken from the soil than from any equal area on earth". Actually, with the exception of two minerals, sulphur and salt, this wealth has been or is being derived from plants. He mentions oil, gas, grass, rice, flax, tung and cotton.

Several years ago I read a remarkable statement. It is found in Loomis and Shull, *Methods in Plant Physiology* (12): "Photosynthesis is the foundation of biology and organic chemistry, the source of building material and energy for plants and animals, and the world's most important source of industrial energy. Not only are we dependent on

plants for all of our food and most of our energy, but perhaps 90 per cent of the world's population is engaged directly or indirectly in the production, transportation, processing or sale of the products of photosynthesis". These are profound statements and have tremendous application with respect to the southern regions. With temperature and light levels favorable for photosynthesis the entire year, combined with the control and application of the adequate water supply, the improvement of soil fertility, the development of labor saving machinery and the use of adapted strains and varieties, high marketable yields of a wide variety of horticultural crops can be obtained. With this procedure combined with the training of students according to their needs and requirements, we shall be doing our part in changing the potentialities into actualities in the shortest possible time. Thus, the grower of horticultural crops in the South and we his servants can, with a fair degree of certainty, face the future with optimism.

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The Cold Resistance of Certain Species of Herbaceous Perennials[1]

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THE COLD RESISTANCE of the numerous species and varieties of ornamental perennials seems to have been given little attention. Many comments on injury to such plants due to frost or winter cold may be found in popular journals. Only a few studies have been made under controlled temperatures such, for example, as that by Hansing *et al* (2) with Sedums. Related studies, such as investigations of the effects of types and depths of mulches upon soil temperatures in winter by Iverson (3) and others have shown what temperatures may occur in the winter environment of mulched plants. As information relating to the cold resistance of perennials was believed to be of interest to both professional and amateur growers the principal studies reported herein were carried on during the winter of 1942–43 following some earlier studies of preliminary nature.

MATERIALS AND METHODS

Four species of herbaceous perennials selected for the study were *Althea rosea, Pentstemon secundiflorum, Lychnis chalcedonica,* and *Papaver nudicaule.* The procedures followed were essentially the same as those found most satisfactory in a similar study of cold resistance in strawberries (1). Seedling plants were grown to maturity in the field. In early October between 200 and 300 plants of each species were selected for uniformity and potted in soil taken from the field. Tops of Lychnis, Pentstemon and Papaver plants were cut back for convenience in handling and some pruning of straggling roots of Althea plants was necessary to facilitate potting. The potted plants were plunged in peat in open frames where they could harden under outdoor conditions. They were watered only enough to avoid injury from drying.

During October and early November the plants were hardened by light frosts. They were mulched temporarily when temperatures below 20 degrees were predicted. After November 20 the mulch was removed only when samples were taken for freezing treatments.

The several exposures to controlled low temperatures were carried on in the low temperature laboratory where automatic controls held variations within 1.5 degrees F. The air was circulated by fans to insure uniform temperature in the chamber.

In November and February, when soil in the pots was frozen, temperature of the samples came to equilibrium with that of the freezing chamber in time for exposure for 6 to 10 hours at the designated temperature. In March, when the soil was partially thawed, exposure was for only 4 to 6 hours because of the additional time required for the soil to freeze.

The first test was made 10 days after the hardened plants were

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mulched. Comparable samples were exposed on December 1, 2, 3 and 4 to temperatures of 27, 21, 16 and 10 degrees F respectively. After the cold treatments the several samples and a comparable one taken from the frames without cold treatment, were thawed for a week in a cellar at 41 to 45 degrees F. They were then moved to a cool greenhouse until growth started and finally placed on a bench at 60 to 68 degrees F where records were made of growth response or injury. Similar tests of comparable samples were made on February 15 to 18 and on March 4 to 7. As records of the growth response following the November test indicated that 27 and 21 degrees F were well above the killing points these treatments were omitted in the February and March tests (except for Althea at 21 degrees F) and exposure to +5 and −4 degrees F substituted. As the latter temperature could not be reached in the laboratory the tests were carried on under outdoor conditions. Length of exposure to this temperature was not determined, but the severe injury or killing in all lots so treated indicated that this temperature was too low for survival.

Results

The data obtained in this study are presented in Table I.

TABLE I—Growth Response of Some Perennials After Exposure to Controlled Low Temperatures (Potted Plants, Ten Pots Per Lot)

Species	Time of Test	Growth Response* (4 Weeks in Greenhouse)						
		Mulched in Open Frames	Temperature Treatments (24 hours†—Degrees F)					
			27	21	16	10	5	−4
		V W D	V W D	V W D	V W D	V W D	V W D	V W D
Lychnis chalcedonica	Nov	10 0 0	10 0 0	10 0 0	10 0 0	8 0 2	– – –	– – –
	Feb	10 0 0	– – –	– – –	7 2 1	4 0 6	0 0 10	0 0 10
	Mar	– – –	– – –	– – –	5 2 3	0 5 4‡	0 4 6	0 3 7
Pentstemon secundiflorum	Nov	10 0 0	10 0 0	9 1 0	7 2 1	8 1 1	8 1 1	– – –
	Feb	10 0 0	– – –	– – –	8 1 1	4 3 3	0 0 10	0 0 10
	Mar	– – –	– – –	– – –	9 0 1	5 1 4	0 8 2	0 1 9
Althea rosea	Nov	9 0 1	5 1 4	4 3 3	4 2 4	0 2 8	– – –	– – –
	Feb	8 0 2	– – –	4 2 4	0 0 10	0 0 10	0 0 10	– – –
	Mar	– – –	– – –	– – –	2 2 6	0 4 6	0 0 10	0 0 10

*V = vigorous; W = weak; D = dead.
†All temperatures in degrees F.
‡Nine plants in lot.

Lychnis Chalcedonica:—This table shows that temperatures of 27, 21, and 16 degrees F caused no injury to this species in November, with the first injury appearing at 10 degrees F. In the February test the killing point for Lychnis apparently was between 10 and 5 degrees F. That a few weakened plants survived exposure to 5 and −4 degrees F in the March test was believed due to shorter exposure at those temperatures. These weak plants nearly all died during the following 3 weeks. The "danger point" for this species apparently is close to 16 degrees and the "killing point" close to 5 degrees F.

Pentstemon secundiflorum:—This species behaved much like Lychnis in that no killing occurred at 27 and 21 degrees F in November.

Results of the February and March tests showed that the "danger point" for this species lies somewhere between 16 and 10 degrees F and the "killing point" close to 5 degrees F.

Althea rosea:—In all tests, as well as in check lots not exposed to low temperatures, this species showed more erratic behavior than Lychnis or Pentstemon. Factors other than cold appeared to contribute to injury, but the data suggest that the "danger point" was between 21 and 16 degrees F and that the "killing point" was close to 10 degrees F. In spite of erratic behavior of the several samples it was apparent that this species was less resistant to cold than Lychnis or Pentstemon. These results with Althea agreed closely with those of preliminary tests conducted in 1940 and 1941.

The data for Lychnis, Pentstemon and Althea in general showed better survival in November than later in the season. This behavior indicated that cold resistance did not increase during winter. The poorer survival recorded in the February and March tests appeared to be due in part to breaking of dormancy in some plants and to soggy soil in the pots following thawing.

Data for Papaver are not shown as the highly erratic behavior of all samples indicated that some factor other than low temperature was the cause of poor survival. It was difficult to keep the plants dormant under mulch, and growth in its early stages tended to begin at temperatures close to freezing. Injury from soggy soil following thawing was pronounced in this species, even when the pots drained well within a few days. Examinations of these plants and also of Althea plants failed to detect presence of disease organisms.

Effect of Ice on Survival

It has been a common belief that perennials such as Althea are likely to be injured or killed when covered with ice in winter. As no injury due to ice alone had been found with strawberries (1) the effect of ice on Althea was studied. In 1938–1939, under favorable weather conditions previous to the icing treatments, there was little difference in survival in lots iced from 1 to 10 weeks. Of the iced plants 78.5 per cent survived and grew vigorously, 10.2 per cent were weak, and 11.3 per cent were dead. Comparable plants mulched to simulate field conditions showed only 25 per cent vigorous, 30 per cent weak and 45 per cent dead. In 1939–40 and 1940–41, when mild weather late in December brought on early stages of growth beneath the mulch previous to icing, only a few of the plants survived. As noted in the study of cold resistance, Althea plants appear to break their dormancy at temperatures close to freezing and also are often injured when drainage is poor. These results suggest that breaking of dormancy and poor drainage may contribute as much or more to the poor survival of Althea plants than low temperatures or ice.

Summary

These investigations indicated that the "danger points" and "killing points" for the species studied were as follows:—*Lychnis chalcedonica:*

16 and 5 degrees F; *Pentstemon secundiflorum,* 16 and 5 degrees F; *Althea rosea,* 21 to 16 degrees F and 10 degrees F; *Papaver nudicaule,* not determined.

As the Lychnis and Pentstemon plants showed little injury at temperatures lower than Iverson (3) found beneath mulches in the field in severe winter it seems unlikely that the species studied will be injured by cold when properly mulched. Althea plants appear to be somewhat less cold resistant but factors other than cold appear to contribute materially to injury.

The species studied did not appear to gain in cold resistance during winter. Poor survival in the February and March tests in some cases was attributed to the breaking of dormancy or to poor drainage.

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Rose Root Studies: Some Effects of Soil Moisture Content

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In a previous paper (3) the authors described a series of experiments on the effects of several environmental factors upon the roots of the rose plant. The present paper gives additional observations made on the plants growing in these experiments which were conducted at the Ohio Agricultural Experiment Station, Columbus, Ohio.

Methods

At the completion of experiments in which rose plants had been growing under different conditions of soil moisture content, the root systems were carefully washed, general observations were made, and samples of root tips, young roots, and old roots taken for observation under the microscope. The general methods used for fixation, sectioning, staining, and mounting were those described by Johansen (2). Tissues were fixed in a solution of 5 per cent formalin and 5 per cent propionic acid in 50 per cent ethyl alcohol. The paraffin method was used followed by a triple stain of safranin, Delafield's hematoxylin, and fast green.

Soil was considered to be dry when the soil moisture content was such that moisture was held under a tension of approximately 25 inches of mercury as indicated by a tensiometer. Moist soil was considered to be soil with a moisture tension of 5 to 8 as indicated by a tensiometer and soil where the moisture tension was approximately 0 was considered to have a high moisture content.

All observations were made on roots of plants of Better Times roses, propagated by stem cuttings. Terminal roots were used for sectioning where they could be distinguished from the less vigorous side or lateral roots.

Observations

Moist Soil:—The following description of the outward appearance and of the structure of rose roots which grew in moist soil is given as a basis for comparison of roots which grew in dry soil, in high moisture content soil, or in water. Root systems were generally light brown in color. The very young roots were white for short distances back from the tips. The roots were highly branched throughout the area in which the roots had penetrated.

Longitudinal sections of root tips indicated that there were three histogens: (a) pleurome; (b) periblem (2 cell layers thick—the inner contributed to cortex and the outer to hypodermis and several layers of cortex as well); and (c) dermatogen-calyptrogen. This is similar to type III-A root tip organization as described by Janczewski (1). Root hairs were present in moderate numbers, the youngest ones being 4.5 to 5 millimeters from the root tip.

The arrangement of the primary xylem was usually triarch or tetrarch although small lateral roots often had a diarch arrangement. Endodermal cells had thickened radial and tangential walls which

stained lightly with Sudan III. Endodermal cells close to primary xylem (passage cells) had either less wall thickening or had none at all. The thickenings were formed at about the same time as primary xylem lignification took place.

After the stelar cambium became differentiated, the pericyclic cells by periclinal divisions became an active phellogen which formed phellum and phelloderm. The endodermis usually remained intact for sometime and increased in size by anticlinal divisions of endodermal cells. The interior of the pericycle cells opposite the primary phloem became filled with dark staining substances. These stained brown with ferrous sulfate and were undoubtedly composed mostly of tannins.

The activity of the pericyclic phellogen was of short duration. The third row of cells inside the endodermis became filled with substances as described for the endodermis and all cell division to the outside ceased. A new phellogen differentiated just inside the tanniferous row of cells and the process was repeated so that the resulting periderm consisted of distinct multicelled layers ensheathing the stele and each layer was composed of one row of tanniferous cells and two rows of non-tanniferous cells. The outer layers of periderm became suberized.

Sometime after the formation of secondary phloem, certain primary phloem cells became fully differentiated as thick walled fibers apparently composed of layers of cellulose and lignin. The xylem ray cells were packed with starch grains.

Dry Soil:—In soil of low moisture content the older roots were long, slender, and dark brown in color. The very young roots were short, brittle, light brown in color, and generally stunted in appearance. There was considerable branching in the region of young roots only. Root hairs were very abundant and were present as close as 0.7 millimeters from the root tip. They became suberized and persisted on roots some distance back from the root tip or as long as the cortex and epidermis were present.

Where part of the roots of the plant was in moist soil, the dry soil root tips had a greater diameter but where all roots were in dry soil, they had a smaller diameter than roots in moist soil.

Tannins and suberin were present nearer the tip and were more abundant in the endodermis and the periderm of roots which grew in dry soil (Fig. 1, A). The layers of periderm usually consisted of one row tanniferous cells and one row non-tanniferous cells.

Soil of High Moisture Content:—Roots which grew in soil of high moisture content were different in several respects from those which grew in moist soil. The old roots were large in diameter with a soft and spongy light brown bark which often exfoliated exposing white layers underneath. The young roots were sparsely branched so that terminal roots predominated. The young roots were large in diameter and white for distances up to 8 to 10 centimeters from the tip. Root hairs were few in number or absent.

There were more undifferentiated tissue and more primary tissue present. The first differentiation of endodermis and vascular tissues was evident farther from the root tip.

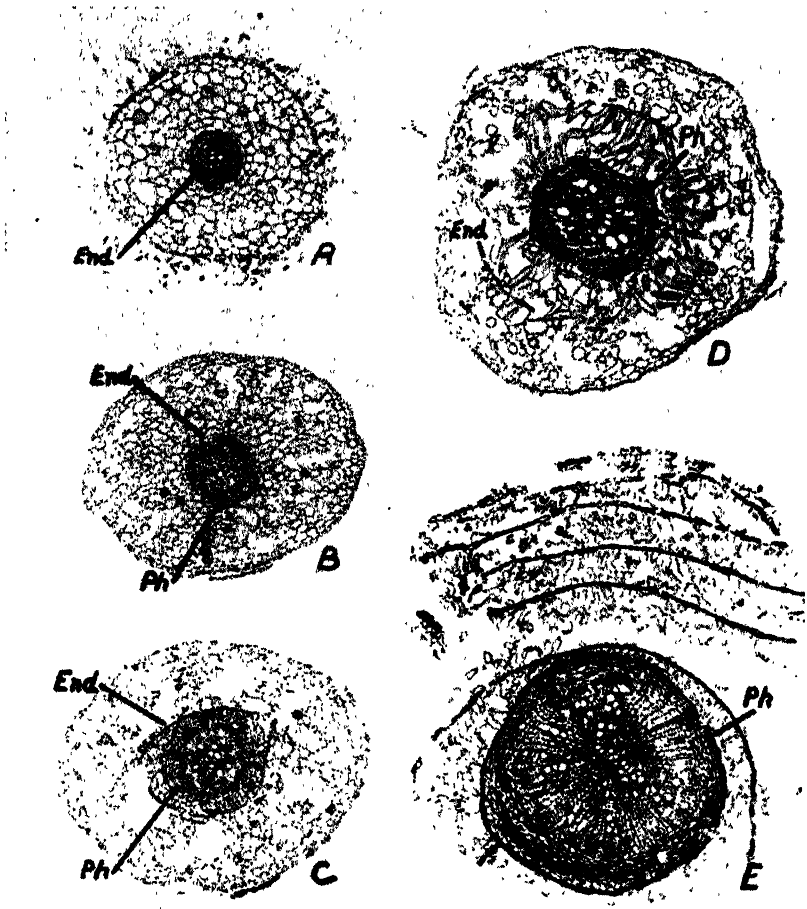

FIG. 1. Transverse sections of rose roots all having same magnification. A, Young root (1.05 mm in diameter) from dry soil showing endodermis filled with tannins and abundant root hairs. B, C, D, E, Successive stages in the development of roots from high moisture content soil. In "B" and "C" the breakdown of cortical cells and formation of pericyclic phellogen. In "D" the radial elongation of cells, rupture of the endodermis, and formation of the second phellogen. In "E" the 7th phellogen is active. Six layers of spongy periderm are evident. End.–Endodermis. Ph.–Phellogen.

Thickening of the endodermal walls took place later than xylem differentiation and then to a lesser extent than that in drier soils. There was little or no deposition of tannins in the endodermal cells.

Cells in the cortex became separated in areas leaving large passage ways, or lacunae, in the cortex. This apparently began about the time of xylem differentiation. The cortex was thick and the cells were large. The periderm formed in layers three or more cells thick with the inner row of cells containing some tannins. The outer several rows of cells

elongated radially to the axis as seen in transverse sections and thick, loose, spongy layers were formed which separated readily from the stele (Fig. 1, B, C, D, E).

The rate of periderm formation was greater than in drier soil resulting in the formation of a many layered periderm 0.07 to 0.13 millimeters or greater in thickness.

Roots In Water:—Where the entire root system of the rose plant was in water, death occurred. Where most of the roots of the plant were growing in favorable conditions in soil, temporary but vigorous roots frequently grew into water below the soil. Although the length of life varied, they remained alive for 6 to 8 weeks in many cases.

The appearance of roots which grew in water was similar to those which grew in high moisture content soil but was more extreme. The older roots had a very spongy bark while the young roots were white for long distances back of the tip (20 centimeters or more) and there was very little branching of the roots.

Differentiated cells were first present relatively far from the tip and there was little or no suberin or tannins evident. The endodermis was often composed entirely of thin-walled cells. There was some plugging of the xylem vessels by unidentified substances.

The duration of activity of the pericyclic phellogens was greater as there were often many more rows of radially elongate parenchymous cells present between the rows of cells tangentially elongate and which contained small amounts of tannins.

Summary

A study of the roots of Better Times roses which had grown in several different moisture conditions indicated that the following were influenced directly or indirectly by the relative amounts of moisture present in the surrounding root medium:

1. Length and diameter of roots.
2. Branching or formation of lateral roots.
3. Number and persistence of root hairs.
4. Differentiation of vascular tissues.
5. Differentiation of the endodermis.
6. Deposition of suberin and tannins, and the presence of passage cells in the endodermis.
7. Formation and duration of activity of phellogens.
8. Presence of lacunae in the cortex.
9. Extent and ultimate form of periderm

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The Effects of Certain Fertilizer Treatments Upon the Growth and Flower Production of Narcissus in North Carolina[1]

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IN 1947 the North Carolina Agricultural Experiment Station, in cooperation with the United States Department of Agriculture, began a series of fertilizer experiments with narcissus at the Vegetable Research Laboratory near Wilmington, North Carolina. The purpose of the experiments was to determine whether narcissus responds to applications of commercial fertilizers and whether heavy applications of mineral nutrients affect the amount of basal rot in bulbs protected with a fungicide. This paper is a report on the effects of various fertilizer treatments upon the yields and the size of narcissus flowers and bulbs in two growing seasons.

Variable results have been reported on fertilizer experiments with narcissus. Emsweller, Randall, and Weaver (1) tested a large number of fertilizer combinations near Castle Hayne, North Carolina, but they found no significant differences in yields of bulbs. Comparisons with unfertilized plots were not made. Higher flower yields resulted from the application of 3 pounds of borax per acre. Parker (2) reported that at Norfolk, Virginia, the use of 1000 pounds per acre of a 2-10-5 fertilizer gave fewer flowers but heavier bulbs. Smith (3) found that in Virginia a fertilizer containing no nitrogen produced bulbs of poor quality, but the earliest flowers. Stuart (4) reported that the effects of fertilizers on flower and bulb production at Beltsville, Maryland, were small but consistent. Nitrogen and phosphorus reduced yields but potassium increased them, apparently because of the influence of these nutrients on the development of basal rot.

The experiments reported herein were conducted on a soil that was low in nitrogen and potassium and high in phosphorus. It was classified as Onslow loamy fine sand. It had grown a crop of daffodils in 1945 and had produced a heavy crop of *Crotolaria striata* in 1946 which was plowed under. The pH range was 5.2 to 5.9.

Uniform, round, King Alfred bulbs that had been grown near Wilmington, North Carolina and dug June 24, 1947, were dipped for 5 minutes in Mersolite 8 (used at the rate of 1 ounce per 50 gallons of water) on June 27. This treatment for control of basal rot is based on unpublished work by W. D. McClellan at the Plant Industry Station, Beltsville, Maryland. The bulbs were stored in trays until October 15 when they were divided into 36 lots of 50 bulbs, each lot weighing 4½ pounds, and again dipped in Mersolite 8 as in June. This treatment was used for protection against Fusarium basal rot. The bulbs were planted October 21, in rows 3 feet apart. Each plot contained

[1]Approved by the Director of the North Carolina Agricultural Experiment Station as paper No. 324 of the Journal Series.

50 bulbs and was 12½ feet long with 3 feet between plots. The eight fertilizer treatments (see Table I) and the unfertilized check plot were replicated four times. The fertilizers were applied in the row and were well mixed with the soil except in the band and side applications.

The yields of flowers from the different treatments were recorded as well as the heights of the flower stalks and the diameters of the flowers. The bulbs were dug on June 15 and 16, 1948 and were weighed and dipped in Mersolite 8. Bulbs from each treatment were kept separate and stored until October 8 when they were cleaned, sorted, weighed, and dipped in Mersolite 8. The same lots of bulbs were planted again on October 15, 1948 in 15-foot plots which received the same fertilizer treatments as in the previous year. Yields of flowers and bulbs in 1949 were again recorded.

Results

The results obtained the first year were in agreement with some of the previous work reported above (1). There were no significant differences in yields of flowers, or in their size, or in the heights of the flower stalks among the fertilizer treatments. Neither were there any significant differences in yields of bulbs at the end of the first season. Loss of bulbs from basal rot was small during the summer storage.

In the second year there were marked differences in yields of flowers and bulbs among the treatments as shown in Tables I to III. The first plants to emerge were those from plots which had received either 1500 pounds of a 4-12-4 fertilizer per acre or 750 pounds of a 4-12-4 fertilizer plus a side application of sodium nitrate. These plants were 4 to 6 inches tall before the plants in any of the other plots began to

TABLE I—Narcissus Flower Yields the Second Year as Affected by Different Fertilizer Treatments

Number and Treatment	Number of Flowers Cut on Dates Indicated					Totals	Mean Per Replicate
	Feb 11	Feb 15	Feb 17	Feb 21	Feb 25		
1. No fertilizer	12	30	62	58	17	179	44.7
2. 250 lbs of 4-12-4 per acre in the row	8	35	81	63	14	201	50.2
3. 750 lbs of 4-12-4 per acre in the row	41	71	70	29	8	219	54.7
4. 1500 lbs of 4-12-4 per acre in the row	144	54	19	8	0	225	56.2
5. 1500 lbs of 4-12-4 per acre (500 lbs at planting, 500 lbs at emergence, 500 lbs at flowering)	78	91	51	14	5	239	59.7
6. Urea-form, 30 lbs nitrogen per acre	25	67	76	28	5	201	50.2
7. 750 lbs of 4-12-4 per acre plus 30 lbs available nitrogen at emergence	114	94	28	4	1	241	60.2
8. 750 lbs of 4-12-4 per acre, plus 30 lbs K_2O at emergence	67	73	50	21	3	214	53.5
9. 750 lbs of 4-12-4 per acre, band application at time of planting	26	59	73	44	10	212	53.0

Differences required for significance:

Total yield	(.05)	6.3
	(.01)	8.5
Yield on Feb 11	(.05)	9.9
	(.01)	13.5
Yield to and including Feb 17	(.05)	8.8
	(.01)	11.8

TABLE II—NARCISSUS FLOWER STALK HEIGHTS THE SECOND YEAR AS AFFECTED BY DIFFERENT FERTILIZER TREATMENTS

Number and Treatment	Average Heights in Inches of Flower Stalks* On Dates Indicated					Mean
	Feb 1	Feb 15	Feb 17	Feb 21	Feb 25	
1. No fertilizer	7.8	8.6	7.4	7.6	6.8	7.6
2. 250 lbs of 4-12-4 per acre in the row	9.9	9.3	9.4	9.9	10.0	9.7
3. 750 lbs of 4-12-4 per acre in the row	10.4	10.6	10.1	10.7	9.7	10.3
4. 1500 lbs of 4-12-4 per acre in the row	11.9	10.2	10.2	10.8	0	10.8
5. 1500 lbs of 4-12-4 per acre (500 lbs at planting, 500 lbs at emergence, 500 lbs at flowering	11.2	10.1	9.9	10.0	9.80	10.2
6. Urea-form, 30 lbs nitrogen per acre	11.9	9.4	8.8	8.3	7.10	9.1
7. 750 lbs of 4-12-4 per acre plus 30 lbs available nitrogen at emergence	11.3	10.2	9.9	8.2	11.0	10.1
8. 750 lbs of 4-12-4 per acre plus 30 lbs K_2O at emergence	10.9	10.1	9.9	10.3	8.1	9.9
9. 750 lbs of 4-12-4 per acre, band application at time of planting	11.0	10.0	10.0	10.1	9.9	10.2

Differences required for significance:
(.05) 1.2
(.01) 1.6

*Heights of the green stems exclusive of the flowers themselves.

TABLE III—YIELDS OF CURED NARCISSUS BULBS FROM DIFFERENT FERTILIZER TREATMENTS*

Number and Treatment	Average Weight (Pounds Per Plot)	Average Number Bulbs Per Plot	Average Weight Bulbs (Ounces)	Average Number Rotten Bulbs Per Plot After Curing
1. No fertilizer	7.98	111	1.15	0.5
2. 250 lbs of 4-12-4 per acre in the row	10.18	107	1.52	0.25
3. 750 lbs of 4-12-4 per acre in the row	11 57	101	1.83	1.5
4. 1500 lbs of 4-12-4 per acre in the row	11.66	98	1.90	2.0
5. 1500 lbs of 4-12-4 per acre (500 lbs at planting, 500 lbs at emergence, 500 lbs at flowering	13.01	109	1.91	0.5
6. Urea-form, 30 lbs nitrogen per acre	8.82	94	1.50	0.0
7. 750 lbs of 4-12-4 per acre plus 30 lbs available nitrogen at emergence	12.25	105	1.87	0.25
8. 750 lbs of 4-12-4 per acre, plus 30 lbs K_2O at emergence	11.71	104	1.80	0.5
9. 750 lbs of 4-12-4 per acre, band application at time of planting	10.56	101	1.67	1.0

Difference required for significance:

Weight of bulbs per plot	(.05)	0.9
	(.01)	1.2
Number of bulbs	(.05)	7.9
	(.01)	10.7
Mean weight of bulbs per plot	(.05)	0.23
	(.01)	0.32

*Each lot of bulbs received the same fertilizer treatment for two successive years, but the bulbs were dug at the end of the first year and replanted in a new location.

emerge. They were 3 inches taller than the other plants at the conclusion of the blooming period.

Both the highest early yields of flowers and the highest total yields were obtained from the series of plots that received either 750 pounds of a 4-12-4 fertilizer per acre plus a side dressing of sodium nitrate or 1500 pounds of a 4-12-4 fertilizer per acre applied either in the row as one application or in three applications—at planting time, at emergence, and at time of flowering, respectively. Plots that received

either no fertilizer or as little as 250 pounds of fertilizer per acre produced fewer early flowers and gave smaller total yields.

High potassium levels were not conducive to good flower production unless the nitrogen level was also high. Where a side application of 30 pounds of available potassium was made at the time of emergence on plots which had been fertilized with 750 pounds per acre of a 4-12-4 fertilizer the yields were no better than those obtained from the use of 750 pounds per acre of a 4-12-4 fertilizer alone. The yields of early flowers were lower on the high potassium plots than on those where both nitrogen and potassium were at a high level, (treatment 4), or where the nitrogen level was high and the potassium level relatively low (treatment 7).

The average heights of the flower stalks from the different fertilizer treatments are given in Table II. Most of the heavier fertilizer applications produced flower stalks that averaged more than 10 inches in height (exclusive of the flowers themselves). Where no fertilizer was applied the flower stalks were 2 to 3 inches shorter. The differences in flower diameters were not significant when analyzed statistically and the data are not presented.

Table III gives the yield data on cured bulbs from the various fertilizer treatments. Bulbs that received no fertilizer produced an average of 7.98 pounds per plot, having a mean weight of 1.15 ounces per bulb. Plots that received 1500 pounds of 4-12-4 fertilizer per acre in three applications produced the greatest yield, 13.01 pounds of bulbs per plot, and their average weight was 1.91 ounces. The yield of bulbs from the 750 pound fertilizer application plus a nitrogen side dressing was not significantly lower than the 1500 pound split application, and the average bulb weight in this case was 1.87 ounces.

Urea-form, a slowly available source of nitrogen, supplied by the Division of Fertilizer and Agricultural Lime of the Bureau of Plant Industry, was applied at the rate of 30 pounds of nitrogen (from a preparation having a U/F Mol. ratio of 1.27) per acre in 1947 in addition to 750 pounds per acre of 4-12-4 fertilizer. The Urea-form (481–B 2) was applied alone in 1948 and resulted in the production of fewer flowers and a smaller weight of bulbs than were produced in the better treatments such as 3, 5, and 7, in which complete fertilizers were used.

Application of the fertilizer in bands 3 inches on either side of the bulbs at time of planting resulted in slightly smaller production of bulbs and flowers than where the fertilizer was applied in the row. However, this method is worthy of further study, since only limited amounts of fertilizer can be applied in the row.

Thus, as shown in Table III, yield of bulbs following application of 1500 pounds per acre of fertilizer in the row was not significantly greater than the yield following 750 pounds per acre of the same fertilizer. When the 1500 pounds was made in three applications the yield of bulbs was significantly greater than when the same amount was applied in the row at planting time (treatment 4).

The results reported herein indicate that the production of good quality, early flowers and large bulbs depends to a great extent upon

the amounts and kinds of nutrients that the bulbs receive the previous year. The bulbs used in the 1947–48 experiments had received an application of 750 pounds per acre of a complete fertilizer in 1946–47. In 1947–48 no differences could be detected between treatments, but in 1948–49 those bulbs that had received no fertilizer for 2 years produced flowers and bulbs that were definitely inferior to those from plants grown at higher nutrient levels. It appears that under average growing conditions sufficient nutrients are stored in the bulbs one year to produce satisfactory flowers the following year.

It may be concluded that in eastern North Carolina, on soils of low fertility, narcissus should receive at least 750 pounds per acre of a complete fertilizer when planted plus a side application of 30 pounds, or possibly more, of available nitrogen at emergence if satisfactory flower and bulb production is to be maintained and if early blooming is desired. It would appear that nitrogen is of especial importance for early flowering. On fertile soils that are relatively high in plant nutrients this might be reduced to 500 pounds of a complete fertilizer plus a side application of 30 pounds of available nitrogen at the time of emergence. A high nitrogen level, or a high nitrogen-high potassium level, seems to be more important than a high potassium level alone, even on soils that are low in both of these elements. However, the greatest yield of bulbs followed moderate applications of complete fertilizer at planting time followed by side dressings of complete fertilizer at emergence and flowering or of nitrogen alone at emergence.

The bulb stocks used in these tests contained a very low percentage of basal rot. It was apparently well controlled by the Mersolite treatment and the fertilizers used had little effect on the disease.

Summary

Narcissus bulbs were fertilized with varying amounts of plant nutrients applied in different ways and times. Each bulb lot received the same treatment in two successive years. There were no significant differences in yields between treatments the first year. The second year the plots that received either no fertilizer or only 250 pounds of fertilizer per acre produced fewer flowers than those that received larger amounts of fertilizer. Best yields of early flowers and of bulbs resulted from the use of either 1500 pounds per acre of a 4-12-4 fertilizer or 750 pounds per acre of a 4-12-4 fertilizer plus a side application of 30 pounds of available nitrogen.

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Pruning Trials on Wisteria Vines

By W. H. CHANDLER, *University of California, Los Angeles, Calif.*

MANY ornamentals with much less beauty in flowers, leaves, and stems than vines of the best wisteria varieties have, and much less ability to flower profusely and dependably in the various situations around a home, are more popular. This lack of deserved popularity is probably due in part to neglect of training. Such strong-growing vines, in spite of exceptionally beautiful flowers, may disfigure a home instead of beautifying it, if they are not so located and trained that they emphasize beautiful lines in the building instead of hiding them. The most effective training of a vine I have seen was on the railing of an outdoor stairway to an apartment. The Chinese wisteria vine was diligently trained to this exact position so that at each level of the stairway an extra profusion of long purple clusters hung; a rather unattractive but necessary structure was made very beautiful by a vine that if left untrained would have become a brush pile covering most of the house.

Two kinds of shoots bear flower buds on Wisteria vines: (a) a shoot that is terminated by a flower cluster usually contains a number of leaves in the axils of which flower buds develop, except at very small basal leaves where the buds are vegetative and remain dormant one to many years; (b) each year a considerable number of shoots grow from such buds at the bases of long or short shoots, on vines of *Wisteria sinensis* and *W. venusta*, even if such shoots become 10 to 20 feet long, nearly all buds at leaves exposed to fairly good light will have rudamentary flower clusters in them by late summer or early autumn as Fig. 1 shows. After the warm winters in southern California, buds on such long, late-growing shoots tend to open a little later in spring than buds on the short shoots that have borne each a terminal flower cluster in the preceding year.

FIG. 1. Flower initials in a Royal Purple wisteria bud in early September. By Mrs. Mary Schroeder and Eldon Cairns.

Some gardeners say that if long shoots are cut back in late summer, flower clusters in the following spring on the part left will be longer. At Riverside two vines each of purple and of white *Wisteria sinensis* of purple and of white *W. venusta,* and of 10 varieties of *W. floribunda,* including Royal Purple, were used to study this response. These vines had been planted in the spring of 1938 to study the effect of dinitro sprays on opening of

the buds after warm winters. The spray caused flowering to be a little earlier in spring but not better; all vines in the planting flowered satisfactorily but a little late after even the warmest winters. Fairly heavy summer pruning also causes flowering to be delayed a little but not less profuse.

On August 27, 1941, 20 long shoots, if the vine contained that many, were tagged in pairs so that shoots in each pair would have the same length and number of leaves, and appearance. On one vine of each variety, one shoot in each pair was pruned August 27, the other left unpruned. On the other vine one shoot in each pair was left unpruned, the other pruned on February 2, 1942. Pruning was cutting back to a stub containing four or five buds. The treatments were repeated in the summer of 1942 and late winter 1943. Effects of the pruning on number of flowers to open per cluster are summarized in Table I.

TABLE I—Possible Effect of Summer and Winter Cutting Back of Wisteria Shoots on Number of Flowers in Clusters from Buds Left

	Flowers Per Cluster	Flowers Per Bud	Number of Buds
Wisteria floribunda Royal Purple			
Spurs from late summer cutting	68	30	39
Spurs from late winter cutting	101	73	53
Basal 4 buds on unpruned shoots	74	18	128
Buds 5 to 8 on unpruned shoots	71	22	128
Buds 9 to 12 on unpruned shoots	58	15	128
Wisteria sinensis			
Spurs from late summer cutting	35	19	76
Spurs from late winter cutting	50	33	42
Basal 4 buds on unpruned shoots	33	20	104
Buds 5 to 8 on unpruned shoots	34	27	104
Buds 9 to 12 on unpruned shoots	35	24	104
Wisteria sinensis alba			
Spurs from late summer cutting	37	27	78
Spurs from late winter cutting	39	27	92
Basal 4 buds on unpruned shoots	32	13	160
Buds 5 to 8 on unpruned shoots	32	20	160
Buds 9 to 12 on unpruned shoots	26	16	160
Wisteria venusta alba			
Spurs from late summer cutting	16	11	20
Spurs from late winter cutting	20	8	28
Basal 4 buds on unpruned shoots	20	10	52
Buds 5 to 8 on unpruned shoots	19	13	52
Buds 9 to 12 on unpruned shoots	18	7	52
Wisteria venusta violaceae			
Spurs from late summer cutting	38	26	49
Spurs from late winter cutting	36	21	79
Basal 4 buds on unpruned shoots	27	10	116
Buds 5 to 8 on unpruned shoots	34	28	116
Buds 9 to 12 on unpruned shoots	32	24	116

Cutting back of shoots caused the clusters on the parts left to be longer and to contain more flowers; and apparently, as the middle column indicates, caused a larger percentage of the buds to produce clusters on vines of most of the varieties. However, buds on shoots pruned in late winter, long after all flowers must have been initiated, produced clusters with as many flowers as buds left on summer-pruned shoots or more. Some of the flower initials are abscised from elongating

inflorescences, and less frequently the inflorescence protrudes a little from the bud and then dies. Abscission of flower initials and dying of protruding inflorescences seem greater at the base and at the apex of long unpruned shoots than along the middle part. Apparently cutting back a shoot in late summer to late winter causes more nearly all the initials in the buds left to become fully developed flowers, and possibly fewer of the inflorescences to die when expanded only a little.

One may want to prune vines severely to get branches out of the way for painting a structure they are on and will then want to know what effect the pruning will have on their subsequent growth and flowering. On June 14, 1946, nearly a month after the flowers had fallen, and after many shoots were 16 to 20 inches long, nearly all these vines (tangled bushes about 10 feet tall and broad) were cut back to branched stubs less than half their former height and spread, many of the cuts where the branches were more than an inch in diameter, nearly all the leaf surface being cut off with the wood removed. New shoots soon started from dormant buds. Some of these on white and on purple *Wisteria sinensis* bore flower clusters in summer, less than 3 months after the pruning was done. Notes on blossoming in the following spring were kindly taken by Roy Nakayama. Both plants of the Royal Purple variety of *W. floribunda* flowered well. So did both plants of white and of purple *W. sinensis* and both plants of white and of purple *W. venusta.* A few plants of other varieties of *W. floribunda* produced enough clusters to make a fairly good showing, but most plants of this species produced very few flowers or none. If the *W. floribunda* vines had not been in full, intense sunlights they would have produced even fewer flower clusters.

Training wisteria vines for good flowering on small lots in some shade might well be about as follows: plant a variety of *Wisteria sinensis* or *W. venusta,* or possibly the Royal Purple variety of *W. floribunda,* and train the young branches in any direction wanted. When the vines begin to grow into positions where they are not wanted, cut off the undesirable parts as soon as all flowers have fallen, shorten unsightly shoots to sightly lengths in summer, possibly shortening them further in late winter, and if such annual pruning does not keep the vines small enough, cut back the whole vine more severely soon after the flowers fall in some springs. Such pruning would tend to prevent flowering on vines of most varieties of *W. floribunda.* On *W. sinensis* and *W. venusta* vines such cutting back large branches and thinning out small ones that have borne terminal flower clusters along the part wanted, will cause the growth of more long shoots that bloom the later in spring and so prolong the season of profuse flowering. Such thinning tends also to space the clusters in better light. In districts where the summers are short and the winters cold, moderate summer pruning or severe pruning at any time may reduce resistance to low winter temperatures.

Rose Root Studies: Some Effects of Root Aeration

By JAMES B. SHANKS and ALEX LAURIE, *Ohio Agricultural Experiment Station, Columbus, Ohio*

IN A previous paper (4) the authors described an experiment in which plants of Better Times roses propagated by cuttings grew with their roots in haydite which was irrigated periodically with a culture solution. As the solution was drained, mixtures of air components were introduced so that the roots of different plants were aerated with approximately 1, 5, 9, 13, 17, 21, 25, and 29 per cent oxygen in nitrogen and 5, 10, 15, and 20 per cent carbon dioxide in nitrogen with 20 per cent oxygen present. Atmospheric air was used to approximate the 21 per cent oxygen gas mixture.

Under the conditions of the experiment the plants grew well under all treatments with no apparent visual differences in the tops. Differences were apparent, however, between the roots of the plants from the various treatments. As compared to the roots in atmospheric air, the young roots in high carbon dioxide concentrations appeared much larger in diameter and were very brittle. The young roots which grew in 1 per cent oxygen were just as extensive as those in atmospheric air, but were much smaller in diameter, were more branched, and were very white in appearance. The present paper reports the results of chemical and anatomical studies on this material.

Two representative plants from each treatment were treated as individuals for the chemical analysis. Each was separated into roots and tops and preserved in 80 per cent ethyl alcohol. One-half gram of calcium carbonate was added to each sample. Each portion was extracted with 80 per cent ethyl alcohol and the resulting extract and residue used in estimating the various soluble and insoluble components. The methods of the Association of Official Agricultural Chemists (1) were followed except in estimating potassium where the ceric sulfate method described by Brown, *et al* (2) was used. Wallerstein's red label invertase was used in the inversion of non-reducing sugars and the results were calculated as sucrose. Portions of the residue were hydrolized by heating with dilute hydrochloric acid and the reducing power of this extract was calculated as starch. The value for the amount of nitrogen in the residue was multiplied by 6.25 and reported as protein.

The methods used for sectioning and staining were those of Johansen (3). The paraffin method was used followed by a triple stain of safranin, Delafield's hematoxylin, and fast green.

RESULTS OF CHEMICAL ANALYSES

Table I gives the results of chemical analyses of the roots and tops of plants which grew with different carbon dioxide concentrations around the roots. Table II gives the results of the analyses of plants which grew with different oxygen concentrations around the roots. The values given represent an average of the two plants which were analyzed from each treatment. The variation in the chemical composition of plants from the same plots was such that the differences found

TABLE I—ANALYSIS OF PLANTS WHICH GREW WITH DIFFERENT CO_2 CONCENTRATIONS AROUND ROOTS PLUS 20 PER CENT O_2

Approx Ave CO_2 Concentration (Per Cent)	Per Cent D Glucose	Per Cent Sucrose	Per Cent Starch	Per Cent Protein	Per Cent Soluble N	Per Cent Nitrate N	Per Cent Ammonia N	Per Cent Amide N	Per Cent K
				Roots					
0	1.52	1.90	21.10	10.80	0.451	0.290	0.052	0.037	1.39
5	1.42	1.78	24.05	11.15	0.618	0.329	0.054	0.071	1.39
10	1.13	1.68	21.40	10.04	0.450	0.369	0.046	0.029	1.20
15	1.68	2.45	23.20	11.66	0.378	0.370	0.032	0.029	1.41
20	1.67	1.89	22.60	11.16	0.434	0.323	0.042	0	1.38
				Tops					
0	2.21	3.54	23.37	14.66	0.235	(Results of chemical analyses calculated on a moisture free basis)			
5	1.45	2.73	22.00	14.98	0.374				
10	2.16	3.18	22.45	15.55	0.297				
15	2.07	2.85	23.42	15.13	0.281				
20	1.90	2.62	23.30	12.91	0.269				

TABLE II—ANALYSIS OF PLANTS WHICH GREW WITH DIFFERENT O_2 CONCENTRATIONS AROUND ROOTS

Approx Ave O_2 Concentration (Per Cent)	Per Cent D Glucose	Per Cent Sucrose	Per Cent Starch	Per Cent Protein	Per Cent Soluble N	Per Cent Nitrate N	Per Cent Ammonia N	Per Cent Amide N	Per Cent K
				Roots					
1	1.65	1.85	23.55	10.58	0.439	0.338	0.042	0.025	1.65
5	1.01	1.13	23.25	11.39	0.521	0.361	0.023	0.025	1.59
9	1.16	1.31	21.90	9.18	0.502	0.278	0.033	0.060	1.48
13	0.74	0.74	21.00	9.71	0.424	0.218	0.043	0.035	0.84
17	1.12	0.71	22.70	9.97	0.515	0.386	0.066	0.036	1.28
21	1.52	1.90	21.10	10.80	0.451	0.290	0.052	0.037	1.39
25	1.94	1.23	21.30	9.69	0.409	0.231	0.034	0.040	1.04
29	0.99	1.13	22.00	10.54	0.441	0.346	0.044	0.044	1.16
				Tops					
1	2.10	3.17	24.62	13.64	0.299	(Results of chemical analyses calculated on a moisture free basis)			
5	1.76	2.64	23.67	14.82	0.202				
9	1.82	2.82	25.16	14.18	0.248				
13	1.73	1.84	22.80	15.01	0.280				
17	1.91	2.56	22.35	16.76	0.285				
21	2.21	3.54	22.37	14.66	0.235				
25	2.53	4.87	27.47	12.65	0.239				
29	2.79	3.74	22.47	15.19	0.222				

between the plot averages would not be significant. In an experiment of this nature where a single factor is progressively increased or decreased, any real differences in the composition of the plants would be expected to fall into a definite pattern. Since this was not the case, it again leads to the conclusion that the results of the analyses for carbohydrate fractions, nitrogen fractions, and potassium were not significantly different because of the differential treatment applied in the experiment. The variations in the chemical composition of the individual plants from the same or different treatments were more likely the result of the various stages of growth of the rose plants, such as breaking

of axillary buds, shoot elongation, and flower formation. Thus, it seems logical to conclude that the chemical composition of the roots and tops, as far as it was determined, indicated that the roots were functioning equally well over the entire range of oxygen and carbon dioxide concentrations used.

Anatomical Observations

The authors in a previous paper (5) described the structure of rose roots which grew under conditions of dry soil, moist soil, and soil of an extremely high moisture content. The structure of roots which grew in an oxygen concentration of approximately 21 per cent and with little carbon dioxide present was similar to that of roots which grew in moist soil.

The structure of roots which grew in concentrations of 5 per cent carbon dioxide or greater was similar in some respects to the structure of roots which grew in soil of high moisture content. The root diameter before secondary thickening had taken place averaged 1.4 mm or approximately one and one-half times the diameter of roots which grew in low carbon dioxide concentrations. Passage-ways or lacunae were formed in the cortex of young roots either by disintegration or separation of cell walls in localized areas. The periderm of these roots showed a definite tendency to form as loose spongy layers due to the radial elongation of certain layers of cells. There was, however, no other similarity to roots which grew in high soil moisture. Lignified phloem fibers were present, neither suberization nor the deposition of tannins appeared to have been inhibited, and many root hairs were present (Fig. 1).

Young roots which grew in 1 per cent oxygen were very small in diameter. The terminal roots averaged 0.65 mm in diameter and lateral roots 0.40 mm in diameter.

All other characteristics of roots which grew under conditions of low oxygen concentrations were similar to those of roots which grew in high moisture content soil. Passage-ways or lacunae were formed in the cortex of young roots as was noted for roots in high carbon dioxide. Wall thickenings were present in the endodermis although these were not so extensive as in higher oxygen concentrations. There was little or no accumulation of tannins in endodermal cells. Very few root hairs were present.

The periderm of roots which grew in 1 per cent oxygen was formed of spongy layers each composed of a row of tangentially elongate cells encircling several rows of loosely arranged radially elongate cells. The number of cell divisions in the pericyclic phellogen appeared to have been much greater as there were a number of rows of meristematic cells present and the resulting periderm was extensive. Tannins were usually not present in the tangentially elongate cells. Very few phloem fibers were present and those were not heavily lignified (Fig. 1).

In 5 per cent oxygen the diameter of the young roots was as great as that in 21 per cent oxygen. Phloem fibers were more abundant in these roots than in 1 per cent oxygen. The periderm showed some accumulation of tannins even though spongy periderm was present.

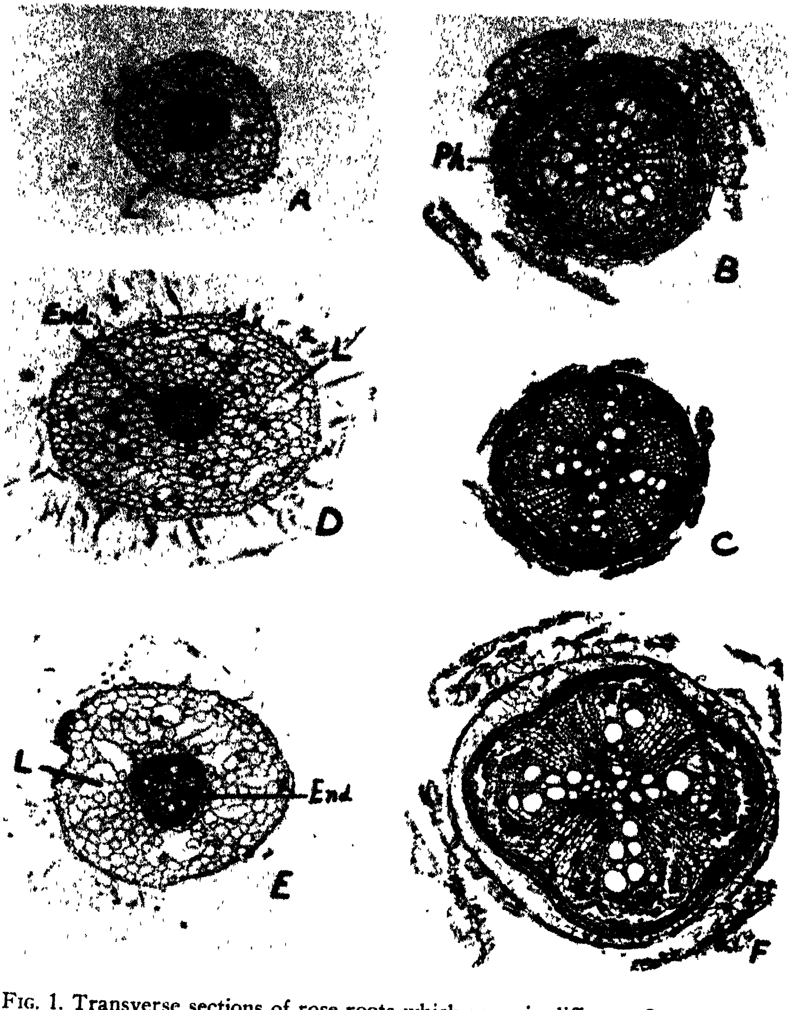

FIG. 1. Transverse sections of rose roots which grew in different O_2 and CO_2 concentrations. (A is .65 mm in diameter; others to same scale) A, Young root from 1 per cent O_2. B, Old root from 1 per cent O_2. C, Old root from 29 per cent O_2. D, and E, Young roots from 15 per cent CO_2. F, Old root from 15 per cent CO_2. Note tearing caused in sectioning by hard phloem fibers.

Ph—phellogen; End—Endodermis; and L—Lacuna.

Roots which grew in 9 per cent oxygen had many root hairs. The endodermis developed heavy wall thickenings but tannins did not accumulate quite so much as in higher oxygen concentrations. Phloem fibers were abundant. Nearly all of the periderm cells were orientated in a tangential plane and were not spongy. Suberization and accumu-

lation of tannins occurred almost as completely as in 21 per cent oxygen.

Roots which grew in 13 per cent oxygen and higher concentrations showed little structural differences except that there was a slightly greater accumulation of tannins in 29 per cent oxygen.

SUMMARY

1. Chemical analyses and an anatomical study were made of the roots of Better Times roses which grew with different concentrations of oxygen and carbon dioxide in the air surrounding their roots.

2. No significant differences in the concentrations of sugars, starch, nitrogen compounds, or potassium were found in the tops or roots of plants which grew in carbon dioxide concentrations as high as 20 per cent or which grew in oxygen concentrations ranging from 1 to 29 per cent. This was interpreted as indicating that the roots of the plant functioned equally well over the range of oxygen and carbon dioxide concentrations used.

3. Carbon dioxide concentrations above 5 per cent were associated with large diameter of young roots, formation of lacunae in the cortex, and the formation of a spongy periderm.

4. Oxygen concentrations of 9 per cent and lower were associated with reductions in the amount of tannins accumulated in the endodermis and periderm and reductions in the degree of suberization of outer layers of the periderm.

5. Oxygen concentrations of 5 per cent and lower were associated with the formation of a spongy periderm and reductions in the number of root hairs formed.

6. An oxygen concentration of approximately 1 per cent was associated with roots of very small diameter, presence of lacunae in the cortex, reduction in the number of heavily lignified phloem fibers present, and an increase in the rate of cell division in the phellogens.

7. Structural differences found in roots which had grown under conditions of high moisture were similar to the collective effects of high carbon dioxide and low oxygen concentrations. The formation of passage-ways or lacunae in the cortex and of a spongy periderm was common to both of these conditions. Associated particularly with high carbon dioxide was the large diameter of young roots and associated particularly with low oxygen concentrations were: (a) reduction in number of root hairs; (b) reduction in degree of thickening of endodermal walls; (c) reduction in amount of deposition of tannins in the endodermis and periderm; (d) reduction in the degree of suberization of the periderm; and (e) increased activity of phellogens.

8. The small diameter of very young roots and the branching of roots associated with low oxygen concentrations were additional characteristics which were not observed on roots grown under conditions of high soil moisture content.

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The Effect of Several Soil Temperatures on Flower Production in Roses

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The successful forcing of roses depends largely upon the proper control of environmental conditions in the greenhouse. Certain of these factors have been widely studied. In this category may be included air temperatures, humidity, atmospheric gases, water requirements, types of media for best growth, pH of medium and fertility levels. However, the matter of optimal soil temperatures for roses had not been previously investigated.

Although the effect of different root temperatures on roses has received little or no attention, there are several reports in the literature concerning work done with other crops. Davidson (4) demonstrated that *Gardenia veitchii* produced more buds and larger flowers when grown at high root temperatures. However, the greatest amount of bud drop occurred on the high root temperature plants, resulting in higher total production for those grown in relatively cool soil. Greenhouse tomatoes, in extensive work by Bewley (3), were shown to respond favorably to increases in soil temperatures above those commonly used. Not only was the growth more vigorous, but yields were increased by as much as 33 per cent over the check plants. Schroeder (9) found cold soil to be the indirect cause of leaf and fruit injury to cucumbers. Unless the soil was warmed to approximately 70 degrees F, water absorption was inadequate to supply the needs of the plant. Other pertinent work has been reported by Allen (1), Arndt (2), Earley and Cartter (5), Emsweller and Tavernetti (6), Jones (7), and Kramer (8). It becomes evident from the literature that at least with certain species, soil temperature may be a limiting factor in production under usual cultural conditions.

Preliminary Experiment

Work of an exploratory nature was accomplished during the season of 1946–47 on the effects of increased soil temperatures upon greenhouse roses. A 100–foot raised cypress bench was planted with two replications, each consisting of three soil temperature treatments. The soil temperatures used were 80 degrees F, 70 degrees F, and unheated check plots which averaged 60 to 65 degrees F during the cooler months. The individual plots were planted with 16 plants each of three rose varieties. Included were Peter's Briarcliff, Better Times and Pink Delight; all were second-year plants, budded on manetti stock. Soil in the bench was new brown silt loam, composted with one part well-rotted manure to four parts soil. Heat was supplied by thermostatically controlled electric cables in the soil. The experimental bench was top-watered. One-inch fiberglass pads were used to cover the soil surface for mulching and insulating purposes. Night air temperatures were maintained at 58 degrees F, 68 degrees F on cloudy days and 73 to 78 degrees F in bright weather. All other conditions were similar to those found in commercial plantings.

The results of this experiment, as given in Table I, showed some advantage in quantity of flowers per plant in all three varieties for the lower soil temperature plots. These differences were considered indicative of a possible retardation in production due to increased soil temperatures, and were used as a basis for further experimental work. Stem length and quality of blooms were largely unaffected.

TABLE I—FLOWER PRODUCTION BY THREE VARIETIES OF ROSES (OCTOBER 1, 1946 TO MAY 20, 1947)

Soil Temperature (Degrees F)	Better Times		Peter's Briarcliff		Pink Delight	
	Average Number Flowers Per Plant	Average Stem Length (Inches)	Average Number Flowers Per Plant	Average Stem Length (Inches)	Average Number Flowers Per Plant	Average Stem Length (Inches)
Check	22.6	16.1	24.1	15.5	16.6	17.9
70	20.2	14.6	20.4	15.0	15.7	17.5
80	18.2	15.1	20.1	15.0	15.0	17.3

EXPERIMENT OF 1947–48

The experimental layout was modified and expanded in the second season so that more complete data could be obtained. Four replications of three treatments each were randomized on two 100-foot raised wooden benches. Only a single variety, Better Times, was used, and each plot contained 48 plants. Temperature levels of the warmed plots were changed to 85 degrees F and 75 degrees F in the second year to give greater differentials between the heated and unheated soils. Another major change was to constant water level culture. With uniform moisture conditions in all plots, there was less possibility of "shock" or injury which may occur when plants are top-watered with cold water. In addition, constant water level culture helps to avoid localized excessive drying around the cables, which might injure portions of the root systems and alter production results. Additional heating cable was incorporated in the heated plots in the second season, being located at the mid-level of the soil and spaced five inches apart. With this arrangement, heating was comparatively uniform and efficient.

The wooden benches were made water-tight with roofing paper and Korite asphalt, and half tiles were run down the center of each for drainage. The bottoms of the benches were filled with B-grade Haydite to a depth of 3 inches and carefully leveled. The remaining 4 inches of each bench was filled with new composted brown silt loam, which was separated from the Haydite by a .025-inch thick fiberglass mat. The fiberglass prevented small columns of soil from sifting down into the Haydite, and made it possible, by merely raising and lowering the water level in the Haydite, to maintain desirable moisture levels regardless of season. A 1-inch fiberglass surface mulch was again utilized to provide insulation and to reduce surface evaporation.

The air temperatures, which were maintained independently of those in the soil, were substantially the same as used the first season. It was found that the check plot soil averaged between 62 and 65 degrees F in the cooler seasons, becoming somewhat higher in late spring

and early fall. Regular spot checks and occasional temperature profiles showed that the soil temperatures in the heated plots were essentially uniform throughout the soil mass, usually within the limits of the thermostat, ± 1½ degrees F.

The plants, new first-year budded stock, were benched on June 26, 1947, soft-pinched until September 15, with production records beginning on October 1. Spacing was 10 inches by 14 inches. Periodic checks showed moderately uniform moisture conditions in all of the plots, regardless of temperature. Monthly soil tests aided in maintaining favorable fertility levels. Superphosphate was incorporated into the soil when the benches were filled at the rate of 2 pounds per 100 square feet. It was not found necessary to supply additional potassium during the experiment. Nitrogen fertilizers used were ammonium sulphate and ammonium nitrate. As anticipated, the warmer plots showed a higher rate of nitration, and less feeding was necessary here. Soluble salt accumulations were at no time excessive. Red spider mite was successfully combatted with TEPP fumigations; black-spot and mildew were prevented with a sulfur-copper 8 spray.

Results and Discussion

The findings for the second year's experiment were very similar to those of the preliminary work. It will be seen from Table II that each increment of soil temperature increase produced a consequent drop in production. Statistically treated by analysis of variance, the results gave a significant difference in production between the check plots and those at 85 degrees F. However, when the production data for variety Better Times were combined for the two seasons, the high soil temperature range showed a highly significant reduction in number of flowers per plant. With the medium range, there was a significant decrease over the check plants.

TABLE II—Summary of Flower Production Data for Better Times Roses Grown at Three Soil Temperatures; October 1, 1947 to July 1, 1948

Soil Temperature (Degrees F)	Average Number Flowers Per Plant	Difference From A	Difference From B
Check (A)	31.7	—	—
75 (B)	30.4	1.3	—
85 (C)	29.8	1.9*	0.6

Difference necessary for significance:
*At 5 per cent level 1.7 flowers per plant.

The total stem length of flowers cut (sometimes termed "total wood cut") on the check plots was greater than on the heated plots. This was primarily due to the greater production on the cooler soil. When these figures were reduced to average stem length of flowers cut on each treatment (Table III), no significant difference appeared.

The plants in the experimental benches were maintained in excellent growing condition during the production period. At no time was it possible to distinguish the various soil treatments by any differences in top growth. Likewise, flower color or quality was not impaired by

TABLE III—AVERAGE STEM LENGTHS OF BETTER TIMES ROSES CUT FROM SOIL PLOTS MAINTAINED AT THREE DIFFERENT TEMPERATURES (OCTOBER 1, 1947 TO JULY 1, 1948)

Soil Temperature (Degrees F)	Average Stem Length (Inches)	Difference From A	Difference From B
Check (A)	20.6	—	—
75 (B)	20.7	0.1	—
85 (C)	20.8	0.2	0.1

any treatment. As in the first year's work, there was no evidence of root injury due to the heating cables.

Under the conditions of the experiment, no apparent benefits were derived from increasing the temperature of rose soil above that normally occurring in unheated plots. Actually, production was adversely affected, with the largest reduction at the highest soil temperature used each season. Thus the findings of this experiment, while demonstrating that roses are less sensitive to changes in soil temperature than had been expected, are still important. The question is posed as to whether or not lower soil temperatures than those found in the check plots would enhance production. This seems doubtful since other warm house crops ordinarily respond poorly to relatively low soil temperatures. For the same reason, it is difficult to explain why increasing soil temperatures, as provided in this experiment, gave negative results. It is possible that warming the soil in the daytime and allowing it to cool at night would be more effective than continuous heating.

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Rose Root Studies: Some Effects of Soil Temperature

By JAMES B. SHANKS[1] and ALEX LAURIE, *Ohio Agricultural Experiment Station, Columbus, Ohio*

PFAHL, Orr, and Laurie (8) in an experiment where the water was warmed to 70 and 80 degrees F before watering the soil in which roses were growing in the greenhouse in winter, concluded that such treatment did not significantly increase the growth of the rose plants. They also observed inhibiting effects at the end of 17 days where the culture solution used to irrigate roses in gravel culture was warmed to 90 degrees F. Fosler and Weinard (3) and Kohl and Weinard (4) controlled the temperature of the soil for roses by warming it to temperatures higher than the prevailing greenhouse temperatures. Soil temperatures of 70, 75, 80, or 85 did not increase the production of roses. Production of roses was significantly less in the 85 degrees F plots than in the unheated plots.

In a previous paper (9) the authors described an experiment in which Better Times roses grew with their roots in soil maintained at temperatures of 52, 57, 62, 67, and 72 degrees F. The greatest growth of the tops of the plants was produced with root temperatures of 62 to 67 degrees F. The air temperature for all treatments was 60 degrees F at night and 65 to 70 degrees F in the daytime. The present paper reports the results of chemical analyses and some anatomical observations on the roots of these plants as well as the results of a second experiment with controlled root temperatures.

PROCEDURE

The same apparatus and methods were employed in the second soil temperature experiment as were previously described by Shanks and Laurie (11). Rooted cuttings of Better Times roses were planted in 4-inch pots in May and placed out-of-doors in partial shade provided by aster cloth. These plants were then brought into the greenhouse and grown in soil temperatures of 56, 60, 64, 68, and 72 degrees F from November 2, 1948 to March 15, 1949. The temperature of the greenhouse where the plants were growing was 60 degrees F at night, 65 degrees F on cloudy days, and 70 degrees F on sunny days. All flower buds were removed by pinching at the uppermost 5-leaflet leaf when approximately ¼ inch in diameter. The total stem length of each plant was recorded on November 2, 1948, January 7, 1949, and March 15, 1949. On this last date, fresh and dry weights of roots and tops were recorded.

The methods used for collecting, sectioning, and staining and for chemical analyses of plant material from the first soil temperature experiment were given in a previous paper (11). A Van Slyke deaminization apparatus was used in the estimation of amino acids.

RESULTS OF PLANT GROWTH

The results of the second soil temperature experiment, summarized in Table I, show that both the fresh and dry weights of roots were

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TABLE I—Soil Temperature and Growth of Roses (Average of 16 Plants)

Soil Temperature (Degrees F)	Growth of Tops				Growth of Roots	
	Increase in Stem Length (Inches)			Dry Weight (Grams)	Fresh Weight (Grams)	Dry Weight (Grams)
	Nov 2-Jan 7	Jan 7-Mar 15	Nov 2-Mar 15			
56	29.75	70.43	100.18	26.44	41.13	8.35
60	31.75	70.12	101.87	26.60	39.25	8.25
64	38.13	92.66	130.79	33.00	39.06	7.93
68	35.56	64.62	100.18	26.72	28.31	6.56
72	33.06	71.87	104.93	27.25	24.00	6.09
L.S.D. at 5 per cent	—	—	24.66	2.88	6.74	1.37
L.S.D. at 1 per cent	—	—	32.80	3.83	8.96	1.82
F	—	—	2.23	6.20**	10.36**	4.61**

less at the high temperatures. In the first soil temperature experiment this was generally true for the same temperature range. In the first experiment, however, the lowest temperature was 52 degrees F in which temperature the dry weight of roots was less than at 62 degrees F.

In the second soil temperature experiment both the dry weight of tops and the increase in stem length were greater at 64 degrees F than at either higher or lower temperatures. This agreed quite well with the results of the first experiment which indicated that the optimum soil temperature for production of top growth of the plant was between 62 and 67 degrees F.

Results of Chemical Analyses

The roots and tops of three representative plants from each plot of the first experiment on soil temperature were analyzed individually for various nitrogen and carbohydrate fractions. Table II shows the results of these analyses. Each value shown is the average of the three plants analyzed.

The percentages of carbohydrate fractions in the tops did not show

TABLE II—Analysis of Plants Which Grew in Soil With Controlled Root Temperatures

Root Temperature (Degrees F)	Per Cent Glucose	Per Cent Sucrose	Per Cent Starch	Per Cent Protein	Per Cent Soluble N	Per Cent Nitrate N	Per Cent Ammonia N	Per Cent Amide N	Per Cent Amino N
				Analysis of Roots					
52	2.73	1.36	24.07	13.61	0.669	0.482	0.079	0.106	0.349
57	1.84	1.19	21.83	12.55	0.730	0.389	0.061	0.110	0.327
62	2.23	1.29	23.87	11.34	0.600	0.246	0.068	0.015	0.187
67	2.21	2.00	25.33	9.42	0.505	0.207	0.076	0.009	0.206
72	1.88	1.70	25.77	8.95	0.503	0.181	0.043	0.015	0.182
				Analysis of Tops					
52	1.76	2.77	22.27	17.22	0.368	(Results of chemical analyses calculated on a moisture free basis)			
57	2.05	2.71	20.81	17.11	0.349				
62	2.04	2.28	22.14	16.63	0.244				
67	2.11	1.98	21.08	15.60	0.239				
72	2.51	2.55	20.81	15.32	0.270				

any correlation with the temperature. In the roots the same was true except that starch was lowest at 57 degrees F and greater amounts were present up to 72 degrees F.

The nitrogen fractions showed a definite correlation with the temperature treatment in both roots and tops. The concentrations of protein and soluble nitrogen were lower at the higher root temperatures in both the roots and the tops: There was less nitrate, amide, and amino nitrogen in the roots at the higher root temperatures. The percentage of ammonia remained fairly constant throughout the different treatments.

Nightingale (7) reported that temperature did not affect the ability of peach and apple roots to absorb nitrate but did affect their ability to reduce and assimilate it. Batjer *et al* (1, 2) found that nitrate and ammonium were absorbed and changed to organic form in apple roots at low temperatures and the translocation to the tops was greatly reduced if the tops were dormant. There was, however, a delayed movement of nitrogen to the tops which, once started, occurred in very large amounts at a root temperature of 42 and 45 degrees F. They state: "It is possible, however, that the reduced water supply (due to low root temperature) was responsible for the reduced growth rate. . . ." Kramer (5, 6) concluded that the principal cause of decreased water absorption of roots at a low temperature was probably due to the effects of decreased permeability of root membranes and the increased viscosity of water.

The greater concentration of protein and soluble nitrogen in both the tops and the roots of the rose plants with their roots in the lower temperatures suggests that the decrease in growth was not due to reduced nitrogen absorption, translocation, or assimilation, but rather that some other factor limited the growth of the plants resulting in an accumulation of nitrogen in the roots and tops. The chemical analyses for carbohydrate components did not indicate that these could have been limiting. The fact that the roots were more succulent at the lower temperatures does not preclude, however, that a reduced rate of translocation of water to the tops could not have been the limiting factor in the growth of the tops. A possible explanation for the reduction of top growth and particularly of root growth at the highest soil temperatures used could not be made on the basis of the data obtained.

Anatomical Observations

The differences in the appearance of roots from the first experiment have already been reported (9). Roots which grew at a temperature of 62 degrees F were similar in their internal structure to roots which grew in moist soil, as described in a previous paper (10). The following characteristics were observed in roots which grew at 52 degrees F:

1. The diameter of young roots averaged 1.5 mm and was greater than in any other treatment (Fig. 1).
2. There was a tendency for pentarch arrangement of the primary xylem. The cortex was thicker because of a greater number of parenchyma cells which were also larger in size (Fig. 1).

3. The endodermis showed only slight thickening of the walls and had little or no accumulation of tannins at the time of first xylem lignification.
4. Periderm formed at a much greater distance from the tip but was similar to that usually found.
5. Phloem fibers were either not present or were very few in number in the older roots.

The following characteristics were observed in the structure of roots which grew in soil at 72 degrees F.

1. The diameter of young roots was less, averaging 0.65 mm (Fig. 1).
2. Root hairs were few or absent (Fig. 1).
3. The endodermal cells were filled with tannins by the time the first secondary tissues were evident.
4. Many phloem fibers were present in the older roots.

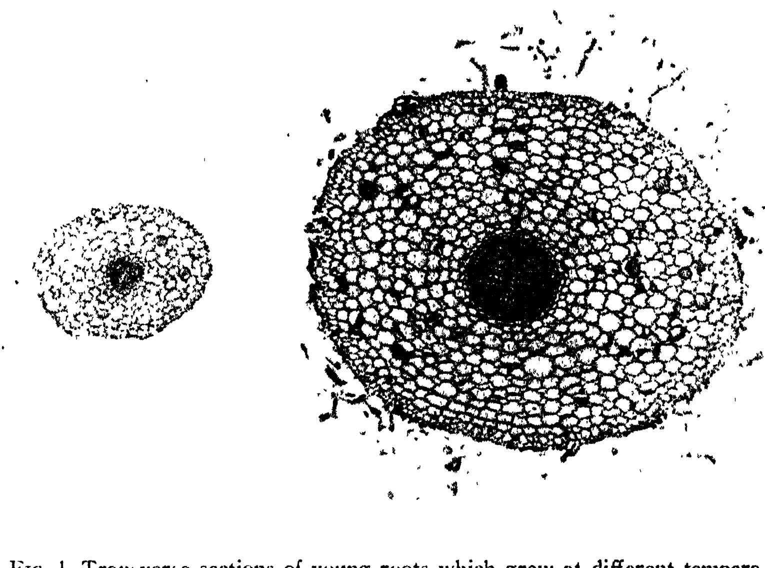

FIG. 1. Transverse sections of young roots which grew at different temperatures; both at same magnification. Left: root which grew at 72 degrees F (0.73 mm diameter). Right: root which grew at 52 degrees F (1.69 mm diameter).

SUMMARY

1. An experiment in which the root temperature was varied at 4 degree intervals from 56 to 72 degrees F gave results similar to a previous experiment so that the following general conclusions were made where the tops of the plants were growing at temperatures of 60 degrees F at night and 65 to 70 degrees F during the day:

a. The optimum root temperature of those temperatures used for the growth of tops was approximately 64 degrees F.

b. There was a progressive decrease in the amount of roots produced per plant as the temperature increased from 56 to 72 degrees F.

2. Soil temperatures influenced the diameter of young roots, number of primary xylem points, amount of accumulation of tannins in the endodermis, number of phloem fibers, and the number of root hairs.

3. There were no great differences in the carbohydrate fractions but there were greater concentrations of the different nitrogen fractions in the roots which grew at lower temperatures.

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Response of Cuttings of Taxus Cuspidata to Treatments Containing Powdered Growth Regulator and Fermate

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A STIMULATING effect of fermate used alone and in combination with various kinds of powdered growth regulators on the rooting of cuttings has been reported. White (6) has reported a greater per cent rooting of geranium cuttings, as well as more and longer roots, following treatment with fermate alone or with fermate in combination with various powdered growth regulators. Swartley (4) has reported an increased per cent rooting with *Viburnum carlesi, V. macrocephalum sterile, V. burkwoodi, Kolkwitzia amabilis,* and *Pieris japonica* when treated with a Hormodin 2–Fermate mixture in the proportions of 5:1. However, both treated and untreated cuttings of *V. tomentosum, V. opulus, Rhododendron obtusum* var. *amoenum,* and *Pyracantha* sp. rooted quickly and in high percentages. Snyder (3) has reported a beneficial effect of fermate-powdered growth regulator mixtures on rooting of cuttings of *V. tomentosum* propagated under certain conditions.

In connection with a demonstration of rooting cuttings of *Taxus cuspidata,* it was observed that relatively large quantities of fermate mixed with powdered growth regulators resulted in an inhibition of the rooting response as indicated after 80 days in the propagated bench. The following experiment was conducted to verify this observation.

MATERIALS AND METHODS

Cuttings of *Taxus cuspidata* were made in August 1948 from growth of the current season. The cuttings were approximately 7 inches in length and the needles were removed from the basal 3 inches. The basal ends of the cuttings were moistened, shaken to remove excess water, and dipped in the powdered material. After being tapped slightly to remove the excess powder, the cuttings were stuck in a coarse grade quartz sand. Nine lots of 20 cuttings each were made for each of the 18 treatments. Three replicates of each treatment were examined at the end of 30 days and the cuttings were replaced in the media to be examined at the end of 120 days. Of the remaining six lots, three were examined after 60 days and three after 90 days. Replicates and treatments were randomized in the propagating bench.

The media was watered over-head as required and the cuttings were shaded with several layers of cheese-cloth. The few cuttings which showed evidence of rot or which died were distributed uniformly throughout the various experimental groups.

Fermate (ferric dimethyldithiocarbamate) was mixed with two commercial powdered growth regulators—Hormodin 2 and Formula 66. The combinations were by weight and are listed in Table I.

A cutting was considered to be rooted if one or more roots were

TABLE 1—PER CENT OF LIVING CUTTINGS OF *Taxus cuspidata* WITH BASAL CALLUS FOLLOWING TREATMENT WITH COMMERCIAL POWDERED GROWTH REGULATORS AND FERMATE USED ALONE AND IN COMBINATION (MIXTURES MADE ON WEIGHT BASIS, DATA BASED ON THREE REPLICATES OF TWENTY CUTTINGS EACH)

Commercial Growth Regulator	Ratio of Commercial Powder to Fermate									Mean
	0	100	99	95	90	75	50	25	0	
	0	0	1	5	10	25	50	75	100	
30 Days										
Hormodin 2	60	30	40	33	28	30	5	15	10	28
Formula 66	50	12	21	15	5	10	8	15	0	15
Mean	55	21	30	24	16	20	6	15	5	21
60 Days										
Hormodin 2	98	88	95	84	76	74	75	78	46	79
Formula 66	85	75	75	77	78	45	48	68	50	67
Mean	92	81	85	80	77	60	62	73	48	73
90 Days										
Hormodin 2	98	100	100	100	100	95	95	100	76	96
Formula 66	100	100	100	95	100	80	72	70	82	89
Mean	99	100	100	98	100	88	84	85	79	93
120 Days										
Hormodin 2	100	100	100	100	100	90	100	100	98	99
Formula 66	100	100	100	100	100	100	94	100	94	99
Mean	100	100	100	100	100	95	97	100	96	99

present regardless of length. The root-rating was determined by scoring the rooted cuttings as follows:

Descriptive Term	Number of Roots per Cutting
Light	1 to 5
Medium	6 to 14
Heavy	15 or more

When warranted, consideration was also given to length of roots. An arbitrary value was given to each of the ratings—light, 1; medium, 2; and heavy, 3—and the average root-rating determined.

RESULTS

Basal Callus Formation:—Since all rooted cuttings examined had also formed basal callus, it was possible to measure the effect of treatment and of time in the propagation medium on this response (Table I). At the end of 30 days, the untreated controls had the highest per cent basal callus formation. More cuttings treated with the Hormodin 2–series were callused than those treated with the Formula 66–series. In the Hormodin 2–series, the number callused decreased with increased quantities of fermate in the mixture, especially with 50 per cent or more fermate. Cuttings treated with fermate alone showed significantly reduced callusing compared with both the untreated controls and with the combinations containing large quantities of the growth regulators. The differences noted above were significant at the 1 per cent level.

After 60 and 90 days in the bench, only the 100 per cent fermate showed a significant reduction in the percentage of cuttings with basal callus. All indications of the inhibitory effect of fermate on basal callus formation had disappeared by 120 days. Differences between the two commercial powdered growth regulators were considerably reduced at the 60-day period and were not significant at the 90- and 120-day periods.

Rooting Response:—The results (Table II) show that no cuttings were rooted at the end of 30 days. At the 60-day period, the untreated controls and all treatments containing the commercial powdered growth regulators included some cuttings which had rooted. No cuttings treated with fermate alone possessed roots. Although analysis of the data showed no significant differences between treatments nor between the commercial growth regulators used, the indications of an inhibitory effect of fermate, as well as a slower response to one of the commercial powders, are substantiated by the results noted at later examination periods.

A significant difference (5 per cent) of the average number of cuttings rooted was obtained between the two commercial growth regulators at the 90-day period. However, there were no significant differences noted at the 120-day period.

The average number of cuttings with roots for the treatments including 25 to 75 per cent fermate were significantly reduced compared with the 100 per cent growth regulator treatment at the 90-day period, but after 120 days only those treatments containing 50 and 75 per cent

TABLE II—AVERAGE NUMBER OF CUTTINGS OF *Taxus cuspidata* ROOTED FOLLOWING TREATMENT WITH COMMERCIAL POWDERED GROWTH REGULATORS AND FERMATE USED ALONE AND IN COMBINATION (MIXTURES MADE ON WEIGHT BASIS, DATA BASED ON THREE REPLICATES OF TWENTY CUTTINGS EACH)

Commercial Growth Regulator	Ratio of Commercial Powder to Fermate									Mean	Least Significant Difference	
	0 / 0	100 / 0	99 / 1	95 / 5	90 / 10	75 / 25	50 / 50	25 / 75	0 / 100		1 Per Cent	5 Per Cent
30 Days												
Hormodin 2.	0	0	0	0	0	0	0	0	0	0	Not significant	
Formula 66 .	0	0	0	0	0	0	0	0	0	0		
60 Days												
Hormodin 2..	2.0	2.0	3.5	3.5	2.0	4.0	0 5	2.5	0	2.3		
Formual 66 .	0.5	2 0	1.5	1.0	3.0	2.0	1.5	2.0	0	2.1	Not significant	
Mean.	1 2	2.0	2.5	2.2	2.5	3.0	1.0	2.2	0	2.2		
90 Days												
Hormodin 2..	9.0	15.0	12.5	13.5	16.5	12.5	12.0	9.5	6.5	11.9	Between commercial growth regulators	
Formula 66..	8.5	12.5	11.5	13.0	11.0	7.0	5.5	7.0	7.5	9.3	3.04	2.24
											Between treatments	
Mean.......	8.8	14.2	12.0	13.2	13.2	9.8	8.7	8.2	7.0	10.6	6.46	4.78
120 Days												
Hormodin 2..	15.5	17.0	16.0	14.5	18.5	16.0	17.5	16.5	10.5	15.8	Between commercial growth regulators	
Formula 66	14.5	17.5	18.0	16.0	18.5	14.0	11.0	12.0	10.0	14.6	Not significant	
Mean... ...	15.0	17.2	17.0	15 2	18.5	15.0	14.2	14.2	10.2	15.2	Between treatments	
											3.20	2.37

fermate continued to show a reduction in rooting. At both periods these treatments were comparable to the untreated controls. The inhibitory effect of 100 per cent fermate on rooting indicated at 60 and 90 days was significant at the 120-day period (1 per cent).

All unrooted cuttings from the 90-day and 120-day treatments were restuck in the propagating medium and after 200 days the average number of cuttings with roots was essentially the same for all treatments (varying from 17.5 to 18.8).

Discussion

The results of this experiment show that treatment of the base of cuttings of *Taxus cuspidata* with fermate used without a wetting agent may inhibit the formation of basal callus and roots. The significant reduction in the number of cuttings callused at 60 and 90 days and the number rooted at 120 days after treatment with fermate compared with the untreated controls indicate that in some manner fermate prevents the functioning of naturally occurring auxins. This inhibitory effect disappears with time since there was no significant difference between the various treatments in the total number of cuttings callused after 120 days and rooted after 200 days.

Although the mechanism of this inhibitory effect is not indicated, it is possible that the effect may be similar to that of 2,3,5–triiodobenzoic acid on rooting as reported by Snyder (2). On the basis of this explanation, it is suggested that a competitive action may exist between molecules of fermate and growth regulator for position on the substrate. Thus, if fermate is not directly effective in stimulating callusing and rooting, occupancy of a relatively large number of positions on the substrate by fermate would reduce the spaces available for auxin to a level below the optimum for rooting. If the growth regulator is available near the lower level of the optimum range, occupation of substrate positions by a relatively large number of fermate molecules could result in a reduced callus or rooting response. Conversely, if the growth regulator is above the optimum for rooting, a reduction of growth-regulator-substrate union would be expected either to increase the responses or to have no effect depending upon the level of available growth regulator and the degree of fermate-substrate union.

It has been shown that small quantities of 2,3,5–triodobenzoic acid will increase the effectiveness of growth regulators (1,2,5). If the mechanism of action of fermate is similar, then use of small quantities might similarily increase the effectiveness of powdered growth regulator. Thus if the available growth regulator is below or above the optimum range, use of fermate could result in increased callus or rooting response. Considering the conditions discussed above, it is relatively easy to account for the reported stimulation, inhibition, and lack of effect of fermate on the rooting of cuttings.

The results reported in Tables I and II show the value of removing cuttings at various intervals rather than the established practice of examining the material at a single period, such as when the untreated controls or a given treatment shows "good" rooting. It is suggested

that if the cuttings are examined at several periods, a clearer and more accurate measure would be obtained of the effect of the various factors which effect the rooting response.

SUMMARY

1. The effect of two commercial powdered growth regulators and fermate used alone and in combination on the formation of basal callus and rooting of cuttings of *Taxus cuspidata* was determined 30, 60, 90, 120, and 200 days following treatment.

2. A comparison of the untreated controls with treatments including growth regulators and fermate used alone and in combination showed an inhibition of callus formation resulting from the powdered material. Mixtures containing large quantities of fermate and fermate alone produced a more pronounced and prolonged inhibition. All inhibitory effects had disappeared 120 days following treatment.

3. In the number of cuttings rooted significant differences between the untreated controls and treatments containing 90 per cent or more growth regulator were noted after 90 days. Only those cuttings treated with a powdered mixture consisting of 90 per cent growth regulator–10 per cent fermate showed significant increase in rooting at the 120-day period. A marked inhibitory effect of fermate used alone was noted at the 120-day period, but had disappeared 200 days following treatment.

4. Differences between the stimulating effect of the two commercial powdered growth regulators were noted at 30, 60, and 90 days, but had disappeared by 120 days.

5. It is suggested that fermate may act as an anti-auxenic material.

6. The value of removing cuttings at various periods following treatment is advisable in order to obtain a true measure of the effects of a given treatment.

7. It is recommended that propagators ascertain the response of a given plant before treating cuttings with fermate used as a dry powder.

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Shredded Sphagnum Moss as a Growing Medium for Newly-Propagated American Holly[1]

By F. L. O'Rourke, *Michigan State College, East Lansing, Mich.*

The numerous selections of outstanding clones of American holly *(Ilex opaca Aiton)* which have been made in recent years have stimulated interest in the vegetative propagation of this species. A majority of nurserymen and propagators favor reproduction by means of cuttings, although some resort to grafting on seedling understocks. It is known that plants which have been produced by grafting will ordinarily make much greater growth during the first year than those produced from cuttings and thus be more quickly available for field planting. Grafting, however, is a tedious process and is dependent upon the production of understocks from seed, which in turn requires space and labor throughout a relatively long period. A method to stimulate growth in plants rooted from cuttings during their first year should have practical application and largely eliminate the need for grafting.

Gardner (1) and Zimmerman and Hitchcock (4) showed that rooting and survival with cuttings of American holly was related to the season of collection of the wood from which the cuttings were made. Fall and early winter collections resulted in a high degree of survival and there was a steadily decreasing trend as collections proceeded throughout the winter. Trees growing under favorable site conditions, however, as when protected from drying winds and deep freezing of the soil, may retain the vitality of their cutting material to a greater degree than those in more exposed locations.

Experimental

Cuttings used in these experiments were collected during the two successive years of 1944 and 1945 on the same date, February 17, from two clonal varieties, Howard and Tabor No. 3, growing in the Tidal Basin area of Washington, D. C., adjacent to the Potomac River. The cuttings were made in the usual way from one-year wood only, 3 to 6 inches long, treated with indole butyric acid in talc, and rooted with 70 degrees F bottom heat in a lean-to greenhouse containing a centrifugal humidifier as described by Stoutemyer and O'Rourke (2).

The cuttings remained in the sand bench from February 17 to April 26 during each of the successive years, and then the rooted cuttings of both varieties were divided into two apparently uniform lots and potted respectively in shredded sphagnum moss and in a specially prepared soil mixture.

The shredded sphagnum moss was prepared by passing dry moss from commercial bales through a hammer mill with a 1-inch screen as reported by Stoutemyer, Close, and Reid (3). The soil mixture con-

[1]This report is the result of investigations carried out by the writer while employed in the Hillculture Section, Office of Research, U.S. Soil Conservation Service, at Glenn Dale, Md. The author wishes to express his appreciation to Dr. Henry Hopp for his kindly direction and assistance with the statistical design and analysis.

sisted of two parts of well-composted loam, one part leaf mold, and one part sand. Each cutting was potted separately in a 3-inch pot, which was given an accession number and plunged in randomized positions in peat moss on the bench of a cool pit greenhouse.

In 1944 the pots were sprinkled at 2-week intervals from the first of June to the last of August with a nutrient solution made by dissolving a tablespoonful of a soluble 12-12-6 fertilizer in a gallon of water. In 1945, feeding with this nutrient solution was started as soon as the new growth appeared shortly after potting. The 12-12-6 fertilizer was supplemented by an additional tablespoonful of ammonium sulphate per gallon and the frequency of application was increased to weekly intervals. Three times during the period of most active growth an additional supply of nitrogen was furnished the plants by applying a solution of 3 tablespoonfuls of ammonium sulphate per gallon of water in addition to the regular weekly feedings. The solution was applied in a sprinkling can equally over all the pots and the plunging medium so that each pot received approximately the same quantity of nutrients. The foliage was washed with clean water after each application.

The position of each pot was changed three times during each season in order to equalize site influence. The new place was determined purely by chance within the variety block.

The nutrient solution and frequent watering were discontinued in September of both years, as in practically all cases the terminal bud had been formed and the tissues were allowed to mature for the winter. In early October all the linear growth produced by the main shoot and side branches for the current year was measured to the nearest centimeter.

Results

The results of these experiments are shown in Table I. During both years the more vigorous clone, Taber No. 3, outgrew the variety Howard in both soil and in sphagnum moss, and in both years sphagnum

TABLE I—Mean Linear Growth (Centimeters) Produced Per Plant of Rooted Cuttings of Two Varieties of American Holly During the First Season After Potting

Variety	Potted in Sphagnum		Potted in Soil		Difference (Cm)
	No. Pots	Mean Growth (Cm)	No. Pots	Mean Growth (Cm)	
		1944			
Howard	48	16.68	49	12.20	4.48
Taber No. 3	33	18.00	34	17.32	0.68
		1945			
Howard	21	25.14	18	17.28	7.86
Taber No. 3	37	25.89	37	21.50	4.39

was superior to soil as a growing medium. The greatly increased growth of both varieties in 1945 over 1944 may be attributed to the more highly concentrated nutrient solution and the greater frequency of application. The significance of the nutrient factor is clearly shown by the analysis of variance reported in Table II. The difference between

TABLE II—ANALYSIS OF VARIANCE OF GROWTH DIFFERENCES

Source of Variation	Degrees of Freedom	Mean Square
Media	1	37.84**
Varieties	1	16.30*
Years	1	82 04**
Interaction—Media × varieties	1	6.62
Media × years	1	6.26
Varieties × years	1	.26
Media × varieties × years	1	.01
Remainder (error)	269	3.42

*Significant at the 5 per cent level.
**Significant at the 1 per cent level.

the potting media is also shown to be highly significant in favor of the sphagnum moss. It is not known whether this superiority may be due to greater aeration with an abundant supply of oxygen available to the roots, to the ability of the sphagnum to absorb ammonium and mineral salts, or to its greater water-holding capacity. In all likelihood a complex of such factors operates to encourage maximum absorption of nutrients which, in turn, promotes growth.

A minor experiment with two other species of holly, *Ilex cornuta*, the Chinese holly, and *Ilex glabra*, the native gallberry, showed approximately the same growth differences in favor of the shredded sphagnum moss. This medium should prove of practical value to propagators to hasten growth during the first season in conjunction with applications of high-nitrogen fertilizer.

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The Influence of a Plastic Resin in Increasing Survival with Summer-Transplanted Evergreens Under Severe Conditions[1]

By J. B. Gartner, F. L. O'Rourke, and C. L. Hamner, *Michigan State College, East Lansing, Mich.*

One of the most pressing problems affecting the nursery and landscape industry is the short season during which ornamental woody plant materials may be transplanted with safety. In view of the acute shortage and high cost of skilled labor, together with the increased demand for ornamental plantings, any material or technique which will extend the planting season should be of great value to landscape nurserymen.

It has been shown by Miller, Neilson and Bandemer (2) that an application of certain wax emulsions will reduce transpiration and aid in the survival of summer transplanted nursery stock.

Hamner, Gartner and O'Rourke (1) have reported the use of a vinyl resin latex in preventing water loss and retaining leaves of cut sprays of spruce, pine and other evergreens. Studies to determine the effectiveness of this substance as a transplanting agent were started during the late spring and early summer of 1948 on the horticultural farm of Michigan State College and at a number of nurseries within the State of Michigan.

The vinyl resin latex[2] consists of particles about .2 micron in diameter suspended in water. The suspension is usually prepared by the manufacturer in a concentration consisting of approximately 51 per cent solids. By diluting this stock preparation with four parts of water, a suspension containing approximately 10 per cent solids is obtained. A small amount of wetting agent, approximately .1 per cent of sodium lauryl sulfate, was usually added to the 10 per cent suspension.

Plants were sprayed thoroughly with an ordinary garden type sprayer to the point of incipient run-off. They were allowed to dry, a matter of 15 to 20 minutes, and were then dug and set in a new location. The vinyl resin emulsion has a milky color while in suspension, but when dry it is entirely transparent, and except for a slight sheen, the appearance of the foliage is normal.

The experiments at the college farm consisted of transplanting 4- to 6-foot white spruce *(Picea alba)* on June 25 to a cultivated field which was very low in soil moisture. These trees were in very active condition of growth at the time of digging. The new shoots were quite soft and tender, and wilted rapidly after the trees were dug. The wilting, however, was much more pronounced with the shoots on the untreated trees. The trees were dug bare-rooted with quite scanty roots.

[1]Authorized for publication as Paper No. 1083 in the Journal Series of the Michigan Agricultural Experiment Station.

[2]This vinyl resin latex formerly was known as Geon 31X and now is called V.L. 600. All material for this experiment was furnished by the B. F. Goodrich Chemical Company of Cleveland, Ohio.

When transplanted, the treated spruce were set alternately in the row with untreated control trees.

Table I shows the result of this experiment as expressed by the condition of the trees at periodic observation periods during the summer. It is evident that while both sprayed and unsprayed trees declined in vigor from the time of transplanting, the majority of the treated trees were always in better condition than an equal number of controls, and at the end of the summer surpassed the controls in both per cent survival and in general condition.

TABLE I—PER CENT SURVIVAL AND SUBSEQUENT CONDITION OF WHITE SPRUCE (*Picea alba*) TRANSPLANTED JUNE 6 AFTER SPRAYING WITH VINYL RESIN LATEX

Treatment	Good (Per Cent)	Fair (Per Cent)	Poor (Per Cent)	Alive (Per Cent)
		June 14		
Check	43	43	14	100
Treated	84	14	0	100
		June 28		
Check	14	43	43	100
Treated	64	28	7	100
		July 12		
Check	14	28	21	64
Treated	64	36	21	100
		August 2		
Check	14	0	14	28
Treated	36	28	14	79
		August 23		
Check	14	0	14	28
Treated	28	14	0	43

On July 7 this experiment was repeated with slightly larger trees, about 7 feet in height. All were dug bare-rooted and transplanted to a dry cultivated area. No water was used for either transplanting or subsequent irrigation. After a lapse of 1 month all untreated trees were dead, but 75 per cent of the treated trees were still green. On September 5, 2 months after planting, 25 per cent of the sprayed trees were in good condition and may be expected to survive.

Tests which were made with balled evergreens in several nurseries showed that survival, and particularly condition, was favored by the application of a latex spray before transplanting. Among the species which responded well to treatment were: *Juniperus virginians ketele*

TABLE II—PER CENT SURVIVAL AND SUBSEQUENT CONDITION OF TWO-YEAR-OLD APPLE TREES TRANSPLANTED JUNE 25 AFTER SPRAYING WITH VINYL RESIN LATEX (OBSERVATIONS MADE SEPTEMBER 21)

Treatment	Number Plants	Strong, Vigorous (Per Cent)	Weak, Defoliated (Per Cent)	Alive (Per Cent)
Check	172	65	16	81
Treated	250	80	11	91

eri (Keteleeri juniper), *Juniperus virginiana canaerti* (Canerti juniper), *Juniperus virginiana burki* (Burki juniper), *Thuya occidentalis* (American arborvitae), *Taxus cuspidata* (Japanese yew), *Picea pungens glauca* (Colorado spruce) and *Buxus sempervirens* (Boxwood).

This plastic resin may also be useful for treating deciduous trees in full leaf prior to transplanting. On June 25 a nursery in southeastern Michigan transplanted a number of 2-year-old apple trees which remained unsold in their heeling-in grounds. The results are shown in Table II. The sprayed trees not only showed a much higher per cent survival but the use of the latex also increased the number which exhibited a strong vigorous growing condition 2 months after transplanting. Not all deciduous trees responded alike to the application of vinyl resin. As an illustration, both Bechtel's flowering crab *(Malus ioensis)* and lilac *(Syringa spp.)* showed symptoms of growth cessation accompanied by the abscission of some leaves. The great majority of deciduous trees and shrubs, however, showed no adverse effects.

The cessation of growth which normally takes place in all plants as a result of transplanting is often prolonged as a result of treating with this plastic resin, but the plant usually regains any loss due to delayed growth renewal by more vigorous production of new shoots when growth finally begins again. It has been noted that when certain plants, notably *Taxus spp.* are sprayed with latex and allowed to remain undisturbed, there is a temporary retardation in growth.

The results of this season's investigations are only indicative. Both the number of plant species used and the number of individual plants per experiment have been small. Further trials are needed to determine the response of individual species, the optimum concentration of the latex as related to plant species and condition of growth, and the possible value of the addition of accessory substances.

Since this experiment many nurseries throughout the State of Michigan have used this material as an aid in transplanting and have reported favorable results.

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A Comparison on Rooting of Cuttings Induced By Synthetic Growth Substances[1]

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Synthetic growth substances have been commonly used throughout the past decade as an aid to the rooting of cuttings of many plant species. Indole butyric and naphthalene acetic acids are generally accepted as the most effective of these substances. Many investigators have preferred the salts of these compounds over the acids because they are more readily soluble in water and have been reported to have a slightly greater stimulatory effect (4).

The present studies were undertaken to determine the relative value of the ammonium, potassium, and sodium salts of naphthalene acetic acid as well as the efficiency of certain less known compounds, notably the triethanolamine and sodium salts of beta-naphthoxy acetic acid.

All substances were incorporated in talc dust according to the method described by Stoutemyer (3). The talc mixtures were uniformly made to contain 1 milligram of the growth substances to one gram of talc (1 part to 1,000 parts of talc).

Softwood cuttings of several deciduous shrub species were utilized as test subjects. Cuttings were made in the usual way, graded for uniformity, the bases treated by dipping in the talc dust mixtures, and set in lots of 20 each in a standard greenhouse cutting bench. Each treatment was replicated several times and set in a randomized position in the bench. All cuttings were made and set on the same day and removed and examined at the same time.

When roots were first observed among the untreated cuttings, all lots were removed from the bench and the individual cuttings were graded into three classes—heavy, medium, and light—in respect to the mass of roots produced. An index number for each lot was then determined according to the method of O'Rourke and Maxon (2). The number of cuttings in each class was multiplied by the arbitrary values of five, three, and one, respectively, for the heavy, medium, and light cuttings, and the products added to form the lot index numbers.

The summation of these index numbers is shown in Table I. Talc alone proved to be a root stimulating agent, as has previously been shown by Hitchcock and Zimmerman (1). The relative quantitative differences between the rooting responses produced by the potassium, sodium, and ammonium salts of naphthalene acetic acid are negligible, and the type of roots produced by these three salts are quite similar, consisting of a series of short roots emerging through the side of the stem from the base to a point from 1 to 1½ inches above the base. The type of roots produced by the salts of beta-naphthoxy acetic acid, however, tend to be more similar to the normal rooting of the control cuttings and those treated with talc only, in which the roots produced are

[1]Journal Article No. 925 (n.s.), Michigan Agricultural Experiment Station.
Thanks are due to the American Cyanamid Company, New York, New York, for supplying the chemicals used in the above-reported experiments.

TABLE I—SUMMATION OF INDEX VALUES OF 5,060 CUTTINGS REPRESENTING 253 LOTS OF FIVE PLANT SPECIES AS RELATED TO TREATING THE BASES WITH THE SALTS OF VARIOUS GROWTH SUBSTANCES IN A TALC CARRIER

Plant Species	No. Cuttings Per Treatment	Total Index Values As Related to Treatment*										
		Control	Talc Only	KNA	NaNA	NH_4 NA	TNOA	NaNOA	KIB	NaBOA	NH_4 BOA	BBOA
Forsythia intermedia	40	128	165	169	162	168	151	156	147	158	151	143
Forsythia suspensa	120	241	297	407	430	440	368	319	279	353	380	347
Ligustrum amurense	140	299	423	368	432	407	479	420	415	347	293	432
Pachysandra terminalis	120	137	182	136	111	116	285	308	294	148	123	176
Weigela floribunda	40	40	53	116	93	95	121	137	103	46	46	58
Total, all species	—	845	1120	1196	1228	1226	1404	1340	1238	1052	993	1156

*Abbreviations refer to the following substances:

KNA Potassium naphthalene acetate
NaNA Sodium naphthalene acetate
NH_4NA Ammonium naphthalene acetate
TNOA Triethanloamine b-naphthoxy acetate
NaNOA Sodium b-naphthoxy acetate
KIB Potassium indole butrate
NaBOA Sodium benzothiozol 2-oxyacetate
NH_4BOA Ammonium benzothiozol 2-oxyacetate
BBOA Butyl benzothiozol 2-oxyacetate

longer but fewer in number and emerge at or very near the base of the cutting.

From the quantitative standpoint, the influence of the beta-naphthoxy acetic salts as compared with those of naphthalene acetic acid varied with the plant subject tested. The Forsythia species responded less well, but the others responded much better to the effect of the b-naphthoxy acetates.

Potassium indole butyrate, a substance commonly used in practice to induce root initiation and growth, was also less effective with the Forsythia cuttings than the naphthalene compounds but was as effective, or even more so, with the other plant species used. The benzothiozol compounds were, on the whole, inferior in rooting response to the other substances used.

Triethanolamine b-naphthoxy acetate may have certain advantages in stimulating rooting, not only from the quantitative standpoint, but also in the more normal type of roots induced on the cutting.

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Comparative Studies of Ammonium Sulfamate, Borax, and 2,4–D for Control of Poison Ivy and Honeysuckle in the National Capital Parks, Washington, D. C.

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POISON IVY, *Rhus radicans* L., and honeysuckle, *Lonicera japonica* Thumb., are important plant pests in many parts of the United States. Poison ivy is native of the United States and has forms that occur practically all over the United States. Honeysuckle is an introduced species, having been brought over to this country in 1806 from eastern Asia. It is now widespread over many areas of the eastern United States.

Poison ivy is a health hazard to many people who are susceptible to a skin irritation condition caused by coming in contact with the plant or contaminated material. Urushiol is the poisonous substance produced in the sap of poison ivy. The dermatitis is often serious, frequently requiring medical treatment or even hospitalization.

Honeysuckle is a pest under some conditions and an asset under others. It is a pest mainly in semi-open woods and along margins of woodlands where light is sufficient to permit it to make rank growth. Under favorable growing conditions it is a vigorous grower and will readily overgrow shrubs and small trees within its path, which gradually become more or less smothered out. It often makes such a dense mat of vines on the ground that it is impossible for tree seedlings even to come through the cover. Fences are often overgrown by this pest and deteriorate rapidly under the weight of its growth and the poorly ventilated conditions created. Honeysuckle, while fairly tolerant of shade, does not have the vigor to climb over and break down shrubs and small trees under moderately well-shaded conditions. Under these conditions it is not a pest and may then provide an attractive ground cover. It is also very useful in holding soil banks in the prevention of soil erosion.

The purpose of this paper is to report studies conducted by the writer on the control of poison ivy and honeysuckle in the National Capital Parks in Washington, 1944 to 1946. The treatments were applied on plots of ½ square rod or 1,000 square feet under a wide range of environmental conditions.

The chemicals consisted of ammonium sulfamate, borax, 2,4–dichlorophenoxyacetic acid (2,4–D) the potassium salt of 2,4–D and a water soluble 70 per cent 2,4–D preparation, supplied through the courtesy of the Dow Chemical Company, as A–510.

Martin (1) in 1940 reported ammonium sulfamate applied as a spray at dilutions of ½ to 1 pound, and at the rate of 10 pounds for 1,000 square feet controlled in most cases a variety of weeds including poison ivy. Yeager (2) in 1942 reported ammonium sulfamate very effective for controlling poison ivy when applied as a spray at the rate of ¾ pound for each gallon on 100 square feet. The writer found under large-scale treatments in 1944, ammonium sulfamate dissolved at ½ or 1 pound per gallon about equally effective for controlling poison ivy when

applied by a high pressure sprayer at about 3 gallons for 1 square rod. Stoddard (3) in 1944 reported borax applied broadcast at 10 pounds for 1 square rod was more effective in controlling poison ivy than ammonium sulfamate dissolved 1 pound for each gallon applied as a spray. Hamner and Tukey (4) in 1944 reported in a preliminary test that 2,4–D showed possibilities for controlling poison ivy, and since then this compound or derivatives of it have been widely publicized for controlling poison ivy and honeysuckle. Crooks (5) in 1945 recommended ammonium sulfamate, 2,4–D and borax as among the most effective herbicides for the control of poison ivy.

1944 Tests

The tests in 1944 involved two series of treatments where ammonium sulfamate and borax were applied at different periods of the growing season. In one series, ammonium sulfamate applied as a spray was compared with borax distributed by hand, while in the other series, ammonium sulfamate was applied wet and dry. The wet and dry treatments of ammonium sulfamate were applied at the rate of 1½ pounds for each square rod, which in the former, was dissolved in 3 gallons of water and in the latter mixed in 8½ pounds of sand. Borax was applied at the rate of 10 pounds for each square rod. The ammonium sulfamate borax series comprised seven plots 1 by ½ rod in size, while the ammonium sulfamate wet and dry series consisted of five similar plots. The plots in both series were separated by 2-foot borders. Each series of treatments was conducted at three different locations. In the ammonium sulfamate-borax series, treatments were made June 3, July 22, and September 14. In the ammonium sulfamate wet and dry series, treatments were made June 3 and September 14. The spray treatments made June 3 were applied by a high pressure power sprayer, while those applied July 22 and September 14 were applied by a knapsack type of sprayer. Estimates were made on the coverage of poison ivy, honeysuckle and other plant growth for each plot before treatment and at various times later. The results of the ammonium sulfamate-borax series are summarized in Table I, while those of the ammonium sulfamate wet and dry treatments are summarized in Table II. A severe drought characterized the 1944 growing season.

Ammonium Sulfamate (wet)—Borax Series:—Under most conditions of the tests, ammonium sulfamate and borax were very effective and compared favorably in controlling poison ivy. Ammonium sulfamate was found ineffective under all conditions of the tests in controlling honeysuckle, while borax usually proved highly effective.

The foliage of poison ivy was found to react very readily to the spray of the ammonium sulfamate, turning black and dying within a week after treatment. The foliage of honeysuckle and other broad-leaved plants in the plots usually were affected like poison ivy, but occasionally the former showed resistance to injury, then usually becoming somewhat blackened or chlorotic. As poison ivy was destroyed by ammonium sulfamate, it was usually replaced by honeysuckle during the remaining or following season.

TABLE I—COMPARATIVE TREATMENT OF AMMONIUM SULFAMATE AND BORAX FOR CONTROL OF POISON IVY AND HONEYSUCKLE

Plot No.	Treatment Per Square Rod	Date Treated	Plant Cover Before Treatment			Control July 12, 1945	
			Poison Ivy (Per Cent)	Honeysuckle (Per Cent)	Misc. Plants (Per Cent)	Poison Ivy (Per Cent)	Honeysuckle (Per Cent)
1-1	Amm. sulfamate, 1½ lbs/3 gals water	Jun 3, 44	79	20	1	99	0
1-2	Borax 10 lbs	Jun 3, 44	82	15	3	98	98
1-3	Amm. sulfamate, 1½ lbs/3 gals water	Jul 22, 44	86	8	1	98	0
1-4	Check	———	99	1	0	0	0
1-5	Borax 10 lbs	Jul 22, 44	90	Trace	3	44	—
1-6	Amm. sulfamate, 1½ lbs/3 gals water	Sep 14, 44	92	7	Trace	57	0
1-7	Borax, 10 lbs	Sep 14, 44	50	50	0	96	90
2-1	Amm. sulfamate, 1½ lbs/3 gals water	Jun 3, 44	50	40	3	98	0
2-2	Borax, 10 lbs	Jun 3, 44	30	65	2	99	99
2-3	Amm. sulfamate, 1½ lbs/3 gals water	Jul 22, 44	35	60	1	91	0
2-4	Check. . .	———	30	65	3	0	0
2-5	Borax, 10 lbs	Jul 22, 44	50	45	1	99	99
2-6	Amm. sulfamate, 1½ lbs/3 gals water	Sep 14, 44	92	7	1	52	0
2-7	Borax, 10 lbs	Sep 14, 44	40	55	2	99	99
3-1	Amm. sulfamate, 1½ lbs/3 gals water	Jun 3, 44	20	76	4	99	0
3-2	Borax, 10 lbs	Jun 3, 44	45	48	3	99	99
3-3	Amm. sulfamate, 1½ lbs/3 gals water	Jul 22, 44	70	26	2	88	0
3-4	Check	———	75	20	5	0	0
3-5	Borax, 10 lbs	Jul 22, 44	65	32	3	99	99
3-6	Amm. sulfamate, 1½ lbs/3 gals water	Sep 14, 44	70	28	2	61	0
3-7	Borax, 10 lbs	Sep 14, 44	55	47	3	80	40

TABLE II—COMPARATIVE TREATMENTS OF AMMONIUM SULFAMATE APPLIED WET (1½ LBS/3 GALS WATER) AND DRY (1½ LBS/8½ LBS SAND) FOR CONTROL OF POISON IVY AND HONEYSUCKLE

Plot No.	Treatment Per Square Rod	Date Treated	Plant Cover Before Treatment			Control Jul 12, 1945	
			Poison Ivy (Per Cent)	Honeysuckle (Per Cent)	Misc. Plants (Per Cent)	Poison Ivy (Per Cent)	Honeysuckle (Per Cent)
4-1	Amm. sulfamate 1½ lbs/3 gals water	Jun 3, 44	34	65	1	97	0
4-2	Amm. sulfamate 1½ lbs/8½ lbs sand	Jun 3, 44	35	55	1	91	0
4-3	Check	———	95	5	0	0	0
4-4	Amm. sulfamate 1½ lbs/3 gals water	Sep 14, 44	95	4	1	47	0
4-5	Amm. sulfamate 1½ lbs/8½ lbs sand	Sep 14, 44	60	37	3	33	0
5-1	Amm. sulfamate 1½ lbs/3 gals water	Jun 3, 44	80	15	5	95	0
5-2	Amm. sulfamate 1½ lbs/8½ lbs sand	Jun 3, 44	82	13	5	99	0
5-3	Check	———	92	7	1	0	0
5-4	Amm. sulfamate 1½ lbs/3 gals water	Sep 14, 44	50	45	5	60	0
5-5	Amm. sulfamate 1½ lbs/8½ lbs sand	Sep 14, 44	55	40	5	36	0
6-1	Amm. sulfamate 1½ lbs/3 gals water	Jun 3, 44	40	55	5	100	0
6-2	Amm. sulfamate 1½ lbs/8½ lbs sand	Jun 3, 44	42	54	4	98	0
6-3	Check	———	45	50	5	0	0
6-4	Amm. sulfamate 1½ lbs/3 gals water	Sep 14, 44	42	56	2	5	0
6-5	Amm. sulfamate 1½ lbs/8½ lbs sand	Sep 14, 44	30	65	5	0	0

The borax treatment was much slower in taking effect on poison ivy, honeysuckle, and other plants in the plots than the spray treatment of ammouium sulfamate, requiring precipitation to wash the chemical into the soil for absorption through the roots before becoming effective. The borax treatment usually developed symptoms of injury in the foliage of poison ivy and honeysuckle about 5 days after the first pene-

trating rain, the foliage gradually becoming brown or chlorotic. Usually about a week after foliage symptoms first appeared, the earliest affected leaves began dropping, and about 5 weeks later practically complete defoliation had occurred.

The time of application was found very important for ammonium sulfamate in the control of poison ivy, whether applied wet or dry, the applications made on September 14 appearing relatively ineffective as compared to the earlier treatments. In the wet treatment, applications made on June 3 and July 22 provided 88 to 99 per cent control, whereas treatments applied September 14 provided only 52 to 61 per cent control. In the dry treatment, applications made June 3 provided 91 to 99 per cent control, while applications made on September 14 provided only 0 to 36 per cent control.

The time of application did not appear important in the borax treatments for the control of poison ivy or honeysuckle, the treatments applied at different times comparing very favorably. Borax-treated plots provided 80 to 99 per cent control of poison ivy with the exception of plot 1–5, where only 57 per cent control was noted, and 90 to 99 per cent control of honeysuckle with the exception of plot 1–5, which showed only 40 per cent control.

The poor control of poison ivy and honeysuckle by borax in plot 1–5 can hardly be related to weather conditions or time of treatment as plots 2–5 and 3–5 treated similarly with borax at the same time provided 99 per cent control for both plant pests. An investigation of the soil reaction in plots 1–2, 1–5, and 1–7 showed 1–5 to have pH 7.6, while plots 1–2, and 1–7 to have pH reactions of approximately 7.1, the difference hardly appearing significant. Karrer (6) found borax more toxic to barley, oats, and sargo plants in acid than alkaline soil. It also appeared possible that a large poison ivy vine having a 2-inch stem near the base, which grew about 40 feet up an American elm in plot 1–5 was a factor in the results. This vine made it possible for plot 1–5 to produce much more poison ivy growth than the other plots, having only the sucker type of ground cover growth. The greater amount of poison ivy growth in plot 1–5 possibly provided for less absorption of borax on a plant material basis and consequently less injury resulted.

Ammonium sulfamate and borax applied dry were found about as effective on steep slopes as on comparatively level ground. These results appeared surprising as it would seem that loss of material from surface run-off on steep slopes would be so great as to greatly reduce the effectiveness of these treatments.

Trees in the borax-treated plots often showed symptoms of borax injury during the season of treatment and in progressively less amounts for 1 or 2 years later. Trees under 20 feet in height appeared more susceptible to borax injury than large trees. One black oak, *Quercus velutina* L., 15 feet in height, and two blue beeches, *Carpinus carolina* Walt., 5 to 7 feet in height proved particularly susceptible to borax injury, which caused general discoloration of the foliage, 10 to 50 per cent defoliation in addition to a moderate amount of twig die-back, during the season of treatment. Three American elms, *Ulmus americana* L., 10 to 45 feet in height, however, were not affected by borax in two

borax-treated plots. Zentmyer, *et al* (7) reported in one experiment where borax was applied at the rate of ¼ and ½ pound to the root zone of American elm trees, 8 to 10 feet in height, no injury resulted, whereas in another experiment where 125 grams of borax were applied to the root zone of American elms 4 to 6 feet in height, very severe injury resulted.

The dry season probably was an important factor in the effect of borax on poison ivy and honeysuckle. Skinner (8) found borax was more injurious to crops when followed by light rainfalls. Heavy rains leached more of the borax into the soil mass, thereby lowering its concentration and enabling the plants to escape injury.

Ammonium Sulfamate – Wet and Dry Series:—Poison ivy was very effectively controlled by either the wet or dry treatments of ammonium sulfamate applied June 3, while similar treatments applied September 14 proved relatively ineffective. The wet and dry treatments applied June 3 resulted in, respectively, 95 to 100 per cent and 91 to 99 per cent control of poison ivy, while the treatments applied September 14 resulted in 5 to 60 per cent control. About a year after either wet or dry treatment of ammonium sulfamate, there was no longer any evidence of control of honeysuckle.

The wet treatment of ammonium sulfamate was relatively fast in taking effect on poison ivy and honeysuckle foliage as compared to the dry. The effect of the ammonium sulfamate wet treatment on the foliage of poison ivy and honeysuckle was the same as described in the former series. In the dry treatment, ammonium sulfamate caused the foliage of poison ivy to curl up slowly, turn brown and drop, complete defoliation usually occurring within 6 weeks after treatment. The foliage of honeysuckle was hardly affected by the dry treatment except for a minor amount of local leaf burning, where apparently the salt had stuck to the leaves when the treatment was applied.

Relatively little of the dry ammouium sulfamate treatment was noticed actually to have adhered to the poison ivy foliage at the time of treatment, which would indicate the effectiveness of the treatment was probably more dependent on its effect from absorption through the roots than through the foliage. There was no indication that dry ammonium sulfamate treatment injured any vegetation other than poison ivy. The dry ammonium sulfamate treatment appeared non-injurious to trees 4 to 6 feet tall of *Prunus serotina* Ehrh., and *Quercus palustris* Muenchh, as well as practically non-injurious to trees of similar size of *Sassafras albidum* (Nutt) Nees., except for a negligible amount of local leaf burning where apparently the salted sand had adhered to their foliage.

1945 Tests

The 1945 tests comprised mostly 2,4–D treatments applied under various conditions as sprays in two series of plots, designated as 7 and 8 at different locations. Ammonium sulfamate applied wet, and borax, dry as usual, were included in the tests of series 8. The plots in each series were numbered in consecutive order. Plots of series 7 were on sandy bottomland, moderately well-shaded by trees, while plots of series 8 were on clay loam soil under deep forest shade conditions.

In series 7, treatments of 2,4–D were applied at concentrations of .1 and .2 per cents on June 3, July 26 and September 13, in addition to .4 per cent for the first two dates. Series 8 received the same 2,4–D treatments as series 4, with the following exceptions: In addition to treating plots with single applications of .1 and .2 per cents of 2,4–D, comparable plots were given double treatments, allowing, however, several hours of drying time between applications. No sprays of the .4 per cent concentration of 2,4–D, however, were applied. Treatments in series 8 were made only on June 3 and July 26.

The .1 and .2 per cent sprays of 2,4–D were prepared by dissolving 1 part of 2,4–dichlorophenoxyacetic acid into 6.3 parts of melted carbowax 1500 and dispersing this solution in the required amount of water, while the sprays of .4 per cent 2,4–D were prepared by dissolving the water soluble A–510 (70 per cent 2,4–D) power directly into water. All sprays were applied at the rate of 3 gallons for 1 square rod in a knapsack sprayer.

Estimates were made on the amount of cover growth of poison ivy, honeysuckle and miscellaneous plants for each plot before treatment and on June 9 of the following year. The conditions and results of the treatments are summarized in Table III. Moisture was very ample, and particularly favorably for plant growth in the Washington area during the 1945 season.

Honeysuckle usually proved very sensitive to 2,4–D causing a general yellowing and wilt of the foliage about 1 week after treatment, followed by more or less complete defoliation about 2 weeks later. The foliage of poison ivy, when sensitive to 2,4–D, gradually turned yellow during about the first 2 weeks after treatment, and was followed by more or less complete defoliation during the next 2 weeks, part of the foliage often turning brown before falling.

The time of applying 2,4–D and the rate of application usually appeared important factors in the control of honeysuckle, while with poison ivy individual plot differences appeared more important. Poison ivy in series 7 showed no control in six of eight plots treated with 2,4–D at concentrations of .1, .2 and .4 per cent. Plots 6 and 9 in this series, however, treated at concentrations of .4 and .2 per cent, showed 42 and 9 per cent control, respectively. In the same series, honeysuckle, however, was controlled 100 per cent by 2,4–D applied at .4 per cent on June 9, while .1 per cent applied at the same time provided only 19 per cent control. 2,4–D treatments applied July 26 or September 13 at concentrations varying from .1 to .4 per cent controlled honeysuckle 17 to 63 per cent, the degree of control, however, showing no correlation with the rate of application.

In series 8, poison ivy was found much more effectively and consistently controlled by 2,4–D than in series 7, the rate of application, however, having little effect on the results. Single and double treatments of 2,4–D at .1 and .2 per cent, applied June 9 controlled poison ivy 52 to 80 per cent, while similar treatments applied July 26 provided 70 to 97 per cent control. The double treatments of 2,4–D showed no advantage over the single in the control of poison ivy.

Ammonium sulfamate and borax were more effective in controlling

TABLE III—COMPARATIVE TREATMENTS OF 2,4-D, AMMONIUM SULFAMATE, AND BORAX FOR CONTROL OF POISON IVY AND HONEYSUCKLE

Plot No.	Treatment Per Square Rod	Date Treated	Plant Cover Before Treatment			Control Jul 12, 1945	
			Poison Ivy (Per Cent)	Honeysuckle (Per Cent)	Misc. Plants (Per Cent)	Poison Ivy (Per Cent)	Honeysuckle (Per Cent)
7-1	3 gals .1 per cent 2,4-D	Jun 9, 45	30	68	2	0	19
7-2	3 gals .2 per cent 2,4-D	Jun 9, 45	32	66	2	0	98
7-3	3 gals .4 per cent 2,4-D (A-510)	Jun 9, 45	30	68	2	0	100
7-4	3 gals .1 per cent 2,4-D	Jul 26, 45	30	68	2	0	63
7-5	3 gals .2 per cent 2,4-D	Jul 26, 45	65	32	3	0	53
7-6	3 gals .4 per cent 2,4-D (A-510)	Jul 26, 45	60	36	4	42	60
7-7	Check	—	65	32	3	0	0
7-8	3 gals .1 per cent 2,4-D	Sep 13, 45	60	38	2	0	53
7-9	3 gals .2 per cent 2,4-D	Sep 13, 45	55	30	15	9	17
7-10	Check	—	35	40	25	0	0
8-1	3 gals .1 per cent 2,4-D	Jun 9, 45	85	0	15	52	—
8-2	3 gals .1 per cent 2,4-D × 2	Jun 9, 45	87	0	13	60	—
8-3	3 gals .2 per cent 2,4-D	Jun 9, 45	75	0	25	80	—
8-4	3 gals .2 per cent 2,4-D × 2	Jun 9, 45	95	0	5	71	—
8-5	Check	—	90	0	10	—	—
8-6	Amm. sulfamate $1\frac{1}{2}$ lbs/3 gals H_2O	Jun 9, 45	92	5	3	97	0
8-7	Borax, 10 lbs	Jun 9, 45	60	30	10	97	97
8-8	3 gals .1 per cent 2,4-D	Jul 26, 45	75	0	25	96	—
8-9	3 gals 1 per cent 2,4-D × 2	Jul 26, 45	95	0	5	92	—
8-10	3 gals .2 per cent 2,4-D	Jul 26, 45	90	0	10	70	—
8-11	3 gals .2 per cent 2,4-D × 2	Jul 26, 45	95	1	4	71	—
8-12	Check	—	70	25	5	0	0
8-13	Amm. sulfamate $1\frac{1}{2}$ lbs/3 gals H_2O	Jul 26, 45	40	55	5	100	0
8-14	Borax, 10 lbs	Jul 26, 45	80	15	5	90	0

poison ivy than the 2,4–D treatments applied June 9, while in the treatments applied July 26, only ammonium sulfamate was more effective. Both treatments of ammonium sulfamate showed no evidence of controlling honeysuckle, while borax was effective in controlling it only in the treatment applied June 9.

Comparison of Fall Treatment of Ammonium Sulfamate During Dry and Moist Seasons in the Control of Poison Ivy:—The relatively poor control of poison ivy by ammonium sulfamate applied September 14, 1944 as compared to similar treatments applied earlier in the season made it appear that the retarded growth caused by lateness of the season and the drought were probably important factors in the results obtained. Yeager (2), in New Hampshire, found ammonium sulfamate was progressively less effective in controlling poison ivy in treatments applied September 18 and October 5, as compared to treatments applied in July and August.

Soil moisture was very plentiful in Washington during the 1945 season as compared to the previous dry season. As it seemed desirable to know if the unfavorable soil moisture in 1944 had been a limiting factor in the poor control of poison ivy by ammonium sulfamate applied on September 14, the test was repeated in 1945 on September 13 at two different locations. Inspection of these plots on June 4, 1946 showed that all but a trace of the poison ivy growth had been killed by the treatment. These results indicate that poison ivy can be effectively controlled by ammonium sulfamate late in the season, provided soil moisture conditions are favorable for growth.

1945 Fall Treatment of 2,4–D

As 2,4–D had appeared very promising in controlling honeysuckle in the spring and summer applications of 1945, it was decided to test this material for controlling honeysuckle growing in and among trees and shrubs, late in the fall of the same year. The main object of testing 2,4–D under the above conditions was to learn if this herbicide was effective in controlling honeysuckle, a semi-evergreen, when still in full foliage, while at the same time not injuring the deciduous plants which had dropped their foliage.

Two plots of heavy honeysuckle growth, located side by side, and containing 1,000 square feet each, were selected for the test. Honeysuckle growth was present to a moderate extent in trees and shrubs in the plots. On November 1, spray treatments of .2 and .3 per cent 2,4–D were applied, respectively, to the honeysuckle growth in each of the plots. The sprays were prepared from the potassium salt of 2,4–D. Ten gallons of spray were applied to each plot by a small power sprayer. The treatments were applied during a period of warm weather. The spray tests were conducted in cooperation with Dr. Fanny-Fern Davis, Turf Consultant of the National Capital Parks.

Observations made July 3, 1946 on the results of the treatments showed that both the .2 and .3 per cent sprays were about equally effective, providing about 82 per cent control of honeysuckle in each plot. Unfortunately, both treatments proved highly injurious to some of the trees and shrubs in the plots. The .2 per cent spray severely injured or killed six *Sassafras albidum* trees of trunk diameters 1½ to 2 inches, injured or killed a moderate amount of twigs in four *Diospyros virginiana* L. trees and two shrubs of *Elaeagnus umbellata* Thumb. The .3 per cent spray caused local stunting and curling of foliage on one tree of *Acer rubrum* of trunk diameter of ¼-inch and one tree of *Cornus florida* L. of trunk diameter of 8 inches. No deciduous trees or shrubs in either plot escaped injury from the spray treatments. However, a total of 19 *Pinus virginiana* Mill., and five *Juniperus virginiana* L. trees, having trunk diameters of 2 to 6 inches in both plots which also had been exposed to the 2,4–D treatments, were not injured.

Discussion

Ammonium sulfamate applied dry at 1½ pounds, in 8½ pounds of sand for 1 square rod, was found to be the most satisfactory treatment for controlling poison ivy. The dry treatment not only provided effective control of poison ivy, but also caused practically no injury to the surrounding young trees, although some of the herbicide must have touched at least part of their foliage but apparently had not adhered sufficiently to cause more than negligible injury. The wet treatment of ammonium sulfamate, while proving equally as effective as the dry in controlling poison ivy, however, was very injurious to the surrounding vegetation, destroying practically all foliage touched by the spray, and often causing die-back of their twigs in the case of woody plants. It was found that ammonium sulfamate could be applied effectively for controlling poison ivy from June 3 to the middle of September, the later

treatments, however, apparently requiring favorable soil moisture for growth, to be effective. Neither the wet nor dry treatment of ammonium sulfamate were effective in controlling honeysuckle, which may possibly be related to the dry season, as under more favorable soil moisture conditions the writer has observed ammonium sulfamate to control honeysuckle effectively.

Borax applied at the rate of 10 pounds per square rod was usually the most effective treatment for controlling honeysuckle, although the results sometimes were erratic. Borax proved injurious to tree growth in or near the treated plots for at least 1 or 2 years after treatment.

The 2,4–D treatments were often erratic in their control of poison ivy and honeysuckle, appearing very effective under some conditions and relatively ineffective under others. Individual plot differences often appeared more important in the effectiveness of the treatments than either dosage or time of treatment.

The 2,4–D applied to honeysuckle in trees and shrubs on November 1, although resulting in fairly effective control of the honeysuckle, was found highly unsatisfactory, because of the injury it caused to the surrounding deciduous growth. Most of the injured trees had lost all their foliage at the time the spray treatments were applied, which indicated that 2,4–D apparently had been absorbed through the buds and tender bark, or both. Pirone (9) has demonstrated that 2,4–D may be absorbed through dormant buds of Norway Maple, *Acer platanoides* L., causing serious distortion of their developing leaves.

Summary

This paper presents studies conducted by the writer on the control of poison ivy and honeysuckle by chemical treatments in the National Capital Parks in Washington, D. C., 1944 to 1946.

The chemicals consisted of ammonium sulfamate, borax, and 2,4–D in the form of the acid, the potassium salt and Dow's A–510 water soluble 2,4–D product.

Poison ivy was found to be effectively controlled by ammonium sulfamate, borax and 2,4–D under some conditions and not under others.

Honeysuckle was found to be effectively controlled by borax and 2,4–D under some conditions and not under others.

Ammonium sulfamate applied wet or dry was about equally effective in controlling poison ivy.

The dry treatment of ammonium sulfamate caused relatively little or no injury to young trees in the treated plots.

The wet treatment of ammonium sulfamate, borax and 2,4–D were usually very injurious to young trees.

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Polyploidy in Fruit Improvement

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In the early 1920's certain little-grown red raspberry varieties which I was then using in breeding had very stout canes with notably broad and thick leaves. Their leaves seemed more resistant to disease than many related varieties then widely cultivated. This character made them desirable for parental stock. However, when crossed with the more common varieties the seedlings produced were relatively sterile. In 1923, Longley (19) found that the common varieties of raspberry had 14 chromosomes in each of their somatic or vegetative cells; that is, they had two sets of seven chromosomes and therefore were diploids. On further examination he discovered that the stout-caned, broad- and thick-leafed group had four sets, or 28 chromosomes per cell, and that the hybrids between these and the common varieties had three sets, or 21 chromosomes, per cell. Both of these latter types are classed as polyploids—forms in which three or more basic sets of chromosomes occur in the somatic cells. The one with four sets is called a tetraploid; that with three sets is classed as a triploid. It was further found that the relative sterility of the triploid hybrids was a result of an unbalanced chromosome system. Thus, over a quarter century ago I was forced to take polyploidy into account in breeding programs—and it has been an ever-present factor in research on the fruits with which I have since worked.

Having found such a condition in raspberry, Longley (17) made a chromosome survey of the strawberry where similar problems had appeared. In that fruit the native wild woodland strawberry *(Fragaria vesca* var. *americana)* was found to be diploid, an open-woodland wild strawberry of central Europe *(F. moschata)* was found to be hexaploid, while our common wild meadow strawberry *(F. virginiana)* and all cultivated garden strawberries were octaploid, with eight sets of chromosomes.

Longley (16) had previously surveyed the blackberries and found a polyploid series ranging from 2 to 12 sets of chromosomes. He also surveyed the blueberry group (18) for F. V. Coville and found three groups: diploid, tetraploid, and hexaploid.

In the raspberry, the tetraploids have strong stocky canes with large thrifty leaves in comparison with the diploid. In the strawberry, the hexaploid is sturdier than the diploid, and the octaploid stronger than the hexaploid. In the blueberry, tetraploids and hexaploids of the same species-group are generally somewhat more vigorous than the diploids. In the blackberry there are strong-growing species in each chromosome group, some of the diploids having about the same vigor as some of the 12-ploid group. But it is plainly evident that the 12-ploid blackberries bear a very different relationship to the diploid blackberries from that of the tetraploid raspberries or blueberries to their respective diploids. A true understanding of the effect of polyploidy and the use of polyploid material in breeding in any group must be based on a knowledge

of the relationship of the polyploids to the lower-chromosome species and forms in that group.

The story of the evolution of the groups from which our small fruits have been derived is shrouded in the mist of the geological past. A botanical friend of mine, particularly interested in such things, informs me that each year evidence is being uncovered, indicating that flowering plants were present much longer ago than we have been suspecting. There is excellent evidence that, could we have walked about in the land a million years ago, we would have found many plants much as they are today. There would have been quite recognizable strawberries; various blackberries would have been present, among them the direct ancestors of our present western trailing sorts as well as the eastern forms; and the blueberries already would have been sorted out into various lowbush and highbush kinds.

There is little question that some of these strawberries, blackberries, and blueberries of a million years ago were almost identical with some now living in our woodlands and meadows, and near moist seepages and streams; yet could we compare those with the living we also would be able to detect another series of changes. Some of these changes have been very slow—the gradual evolution which one might expect over a long period of time. But had we been present throughout the period and able to watch these changes, it also would have been evident that evolution did not always proceed at a steady pace, for outside factors often influence and accelerate the development of new and different sorts. There is excellent evidence that, in the blackberries there has been a fairly recent and extremely rapid development of new forms—even within the last 200 years; the blueberries also have been evolving for a very long time, but certain types seem to have appeared only within the last century, and there is abundant evidence that newer forms are currently being evolved in the wild. The majority of these are polyploids (7).

A review of what has happened and is happening in these fruits is especially timely because of Waldo's work (24) on the origin of the Logan and Mammoth blackberries reported to this Society 2 years ago; because of the report on "giant" apples at the same meeting; and because of the recent work of Bain and Dermen (10) in producing tetraploid cranberries. The methods of nature through the ages are beginning to be better understood, and methods are being used to forward fruit improvement (for man's use), so that as much can now be accomplished in breeding plots in a few years as by chance in a hundred thousand or a million years under the slow hand of time.

Strawberry

The geologically ancient ancestors of our modern strawberries were, of course, diploids. A basic diploid, *Fragaria vesca,* still occurs in many parts of the northern hemisphere in a series of forms (and under various names); it still is the most widespread native strawberry; it is also now present naturalized or native in the Andes Mountains and other parts of the temperate southern hemisphere. It seems likely that other ancestral diploids once were present; extensive and detailed

exploration may yet uncover additional living forms. Today, there occurs sporadically in central Europe another, a hexaploid strawberry, *F. moschata*. It resembles the diploid *F. vesca*; its flowers and berries are somewhat larger, but its flowers are not always fertile. It is our supposition that the material called *F. moschata* originated through the union of normally reduced pollen grains with unreduced eggs, which resulted in triploid plants. These autotriploids apparently did not have the necessary fertility to survive for any great length of time as natural populations. But when such triploids double their chromosome number, hexaploids would be produced, and these would be sufficiently fertile to persist, at least locally. The sporadic nature of the present distribution of the wild *F. moschata* lends support to this hypothesis; it appears to be a semi-fertile species that arose out of the more common and widespread diploid *F. vesca*. It is what the botanist calls a polytopic species, a species that arose at various times and in various places from a common ancestor. There is every reason to suspect that new, local, hexaploid populations of *F. moschata* may still be arising; but, because of their low fertility, they rarely would be able to form effective natural populations. Some of these sporadic local races have been selected; and named varieties are occasionally found in European gardens.

Our cultivated strawberries are octaploids and, we must suppose, also have evolved from diploid ancestral forms, possibly as autopolyploids from the same *Fragaria vesca*, but more probably as allopolyploids from two or more allied species now extinct. There are three known octaploid species: *F. virginiana*, our eastern meadow strawberry; *F. ovalis*, the western field strawberry; and *F. chiloensis*, the Pacific beach strawberry—and all enter into cultivated varieties, though the western field strawberry but a little and that only in recent years (5, 15). These three species are all North American, but the beach strawberry is also found in Chile and on the tops of the mountains in Hawaii. Recent reports indicate that related octaploid forms may exist on the mountains of the Island of Formosa and of southwest China. Though the diploid ancestors are probably extinct, we may yet find forms related to *F. vesca* from which by crossing, followed by doubling and redoubling of the chromosome sets, we can reconstruct species similar to each of the present octaploid wild species.

Be that as it may, with such a view of the origin of our strawberries we can utilize much better what we have. Thus, Dermen doubled the chromosome number of *Fragaria vesca* (11). This experimentally induced tetraploid was crossed with the octaploid garden strawberry; the result was a series of hexaploids. These hexaploids were nearly sterile but were back-crossed to octaploid garden strawberries and some fertile seedlings were obtained. These fertile seedlings were found to be 7-ploids and 10-ploids; it is a pleasure to record that they preserve the desirable fragrance of the *vesca* parent. Such success indicates the satisfaction of work with the strawberry and suggests that only pioneering work has as yet been done.

Blackberry

The blackberry furnishes a notable instance of a polyploid series in both wild species and cultivated varieties. Varieties are actually in

cultivation that make up a polyploid series of 2, 3, 4, 6, 7, 8, 9, and 12 sets of chromosomes (6, 14). Representatives of all of these except the 3-, 7-, and 9-ploid forms have been selected from the wild. There are reasons to believe that many species of this native polyploid series are fairly ancient. Polyploidy has been effective in the evolution of blackberry for a long time, both in this country and in Europe, and is probably particularly effective today. Here in the Eastern States, since the forests have been cleared, there are diploid, tetraploid, and hexaploid species growing side by side—and bees are making their hundreds of millions of cross pollinations each year. Tens or hundreds of thousands, or millions, of these crosses are between species with different chromosome numbers, and from these crosses new forms are continually arising. Furthermore, from the relatively few crosses made by scientists, Waldo has recently selected the 9-ploid Cascade variety which, in addition to being the finest flavored of all blackberries yet known, also must be considered a new species and a new polyploid type (23). Recently, also, he has crossed the tetraploid Eldorado variety with an octaploid native blackberry and thus produced a whole population of hexaploids constituting what amounts to a new species of the Mammoth type (24). Crane and Thomas in England (2) have produced a thornless tetraploid blackberry, Merton Thornless, which we can cross with hardy American tetraploids, thus opening up additional possibilities.

In the blackberry, there are still many problems in polyploidy awaiting solution. A notable one concerns the widespread very hardy thornless blackberry, *Rubus canadensis*. We would like to use it in breeding but, thus far, have not been able to do so. Though a wide ranging species, it is triploid everywhere insofar as is known. Bailey (1) has surveyed the forms related to it and described some 17 of the numerous forms of it which occur in the wild. It may well be that a diploid, a tetraploid, and even a hexaploid may be found among them that would be extraordinarily useful to breeders in getting thornless blackberries.

Raspberries

I have told of being forced into a position of interest in the polyploid condition of the raspberry. The discovery of the usefulness of colchicine in producing polyploids led to tests of its use on raspberry seedlings, on growing points, and on root cuttings. Treatment of very young seedlings was successful in producing polyploids, but during the war period they were lost. Nevertheless, we have in colchicine a new tool to make polyploids if we need them badly enough. There are upward of 200 species of raspberries in Eastern Asia with new horticultural qualities that have never been utilized in breeding. If they do not prove fertile in intergroup hybrids, possibly they may if tetraploidy is induced by the use of colchicine. In each such tetraploid it is possible that the plant will function as a diploid (technically called an amphidiploid or amphiploid) and fertility will thus be restored. The opportunities are there. The small number of tetraploid red raspberries found by breeders during recent years seems to indicate that in this fruit polyploidy is just becoming established; that we are sitting on the side lines and

seeing a major advance in the horticultural evolution of this fruit, Crane and Lawrence (3) suggest that polyploidy in the red raspberry has begun only within the past 80 years.

Waldo (24) has been successful in using one tetraploid raspberry in crossing with octaploid blackberries and has produced a whole new series of Loganberry-like fruits. Crane (4) in England had already shown that ordinary reduced pollen of a diploid raspberry would not do in such a cross, that two sets of raspberry chromosomes were needed with four sets from the blackberry to make a Logan-like fruit. These Logan-like berries constitute a new hexaploid species, which has been named *Rubus loganobaccus* by Bailey. It came into existence in 1880 or 1881 when an insect made the cross and Judge Logan planted the seed from which the first Loganberry came. Theoretical considerations indicate that a similar cross of a tetraploid raspberry with a 12-ploid blackberry would be fertile and might also be of great value. It would likely be an octaploid and would constitute another new species type. But most of all we need both hardier tetraploid raspberries and hardier octaploid blackberries to hybridize to produce hardier Logan-types.

Blueberry

The development of the blueberry has occurred within the lifetime of most of those present. But the development of the blueberry as a fruit has occurred through millions of years, and polyploidy has played a large part in the process. The cluster-fruited blueberries in which scientists are interested are mostly eastern North American. There are about seven or eight diploid species, seven or eight tetraploid species, and three hexaploid species. It is particularly interesting to find both diploids and tetraploids of several of the same types of blueberries still growing in the same areas. Evolution in the wild is very active in this fruit today, just as it is in the blackberry. Several blueberry species are important in that their fruit is harvested in the wild, but those that have been most important in the origin of cultivated varieties are the tetraploid highbush, mostly of the Atlantic Coastal region, the tetraploid lowbush of the Northeast, and the hexaploid rabbiteye of southern Georgia and northern Florida.

In the Southern States one ancient species is the diploid *Vaccinium tenellum*, a low-bush drought- and heat-resistant form. In part from this species and also from a series of common ancestral species the drought- and heat-resistant hexaploids *V. amoenum* and *V. ashei* (the rabbiteye) have evolved—the rabbiteye with the most vigorous and productive bush of all blueberries. The hexaploid *V. amoenum* is widely distributed in the southern States and may have evolved before the Ice Ages from the diploid *V. tenellum*. The hexaploid rabbiteye appears to be younger, seemingly having developed, in part, only within the last 15,000 to 20,000 years, much of this development having taken place only within the last century. The majority of the plants of it found in western Florida grow in what were rice fields, which the rabbiteye blueberry invaded when the plantations were abandoned during the war between the states. We have found no tetraploid of the rabbiteye group. We, therefore, crossed the diploid with the hexa-

ploid and this past year have obtained a tetraploid; this has already been used to cross with the highbush to obtain hybrids with the earliness of the highbush and the plant qualities of the rabbiteye. Though we have experimentally produced a new and, we hope, very useful species just this past year, it is hardly possible that nature has not already evolved this or closely similar species, for the hexaploid and diploid species are growing together in the South. As occurs so often, we have not sufficiently surveyed what nature has done for us and, in this case, have found it easier to make what we want.

Stanley Johnston surveyed the lowbush blueberry of Michigan to select the best individuals for crossing with the highbush. Among the selections was Michigan lowbush No. 1. It seems to be, however, what we had been searching for—a tetraploid hybrid involving genes both of the very hardy light blue Canadian blueberry, *Vaccinium myrtilloides,* and of the lowbush species. It is probable that an unreduced pollen grain of the diploid Canadian blueberry fertilized a normal egg of the tetraploid lowbush to produce the Michigan No. 1, or its ancestor. At any rate, in this selection, or in others yet to be discovered, we should find some of the desirable qualities of this Canadian blueberry species which we wish to utilize in breeding.

CRANBERRY

There are at present three recognized species of cranberry in the world; two are diploid and the third is tetraploid. As in the case of the blueberry, the diploid and tetraploid cranberries do not cross. The large acreages of cultivated varieties are now composed entirely of diploids, derived from the southernmost species. A more northerly and hardier species is tetraploid. To cross the commercial diploid varieties with the wild tetraploid, Dermen and Bain proceeded as follows: they used colchicine to produce tetraploids of a majority of the cultivated varieties; these were then crossed with individuals of the more northerly wild tetraploid. The induced tetraploids of the cultivated varieties have been crossed and selfed, and these are now in the field for fruiting tests. The results are most promising. As yet there has been no opportunity to cross the extremely hardy high-arctic diploid species with the southern, commercial diploid varieties. When this is done, the best of the resultant hybrids could then be changed into tetraploids by the use of colchicine; following this the material then could be hybridized with the best of the new tetraploid races now undergoing field tests. The final selections would probably be a series of new super-hardy cranberries.

GRAPES

With the experience with small fruits, briefly described above, our interest has been greatly aroused by the reports of Olmo (21) on his observations and studies on tetraploid grapes and by the samples of tetraploids of both Portland and Fredonia varieties seen during the past 3 years. The clusters of the tetraploid forms of these two varieties were fully developed and the berries almost exactly twice the weight of the corresponding diploids. The size and character of tetraploids

of varieties, and Olmo's report on the very large size of berries of his seedling tetraploids, indicate that breeding of grapes on the tetraploid level may be of immediate value in obtaining very large-fruited commercial varieties.

Apples

Commercial apple and pear varieties are either diploid or triploid. Triploid apples and pears are exceptional among fruits in being sufficiently productive to become important varieties, though they develop few seeds, require cross-pollination, and are poor pollinators. The triploid apple varieties such as Baldwin, Stayman Winesap, Arkansas, and Rhode Island Greening, have all been chance seedlings. They develop into large excellent trees, and we would like to produce triploids at will in breeding.

Nilsson of Sweden has reported (20) obtaining tetraploid seedlings from triploid varieties and has already used the tetraploids extensively in breeding to obtain thousands of triploids and some additional tetraploids.

Giant-fruited apple "sports" have been collected by V. R. Gardner and Roy Gibson at the Graham Station, Michigan, and W. H. Thies has propagated a "giant" McIntosh at the Massachusetts Station. These and other facts with the small-fruit experience as a background suggested that giantism in the apple is due to tetraploidy. Studies by Dermen (8, 9) and by Einset (12, 13) have shown this to be the case. It has been demonstrated that many of the trees producing the "giants" are chimeral diploid-tetraploid mixtures having a tetraploid cortex, stele, and pith of the trunk and branches inside a diploid epidermis, and a diploid outer cortex. The origin of the reproductive tissues is from the diploid outer cortex; however, Dermen is now attempting to make full tetraploids of all the "giant" varieties through adventitious bud development, so that breeding may be done on the tetraploid level with our best varieties, or so that tetraploids of known varieties may be crossed with diploids to make triploids.

Pears, Peaches, and Cherries

Most American pears are diploids, but many triploid varieties are grown in Europe. Two giant sports, both tetraploids, have recently been reported—one of Bartlett in the United States and one of Fertility in England. The variety Fertility is self-sterile on the diploid level but self-fertile as a tetraploid. By the use of colchicine, Dermen has obtained tetraploids of the Michigan No. 504 pear and some others, has used the tetraploid No. 504 in a limited amount of crossing with diploids, and has obtained a dozen triploid plants.

In the peach, until recently, only diploid varieties have been known However, tetraploids of the Golden Jubilee, Halehaven, and Elberta varieties, and of an unnamed selection, have now been obtained by the colchicine technique; when they blossom, breeding can begin on the tetraploid level. One chance triploid peach has proved to be completely sterile, although it appears to have some good pollen.

The sweet cherries are diploid, the sour cherries tetraploid, and the

dukes, supposed hybrids between the sweet and sour, also are tetraploids. How the tetraploid dukes originated from tetraploid x diploid parents is not yet fully known. However, it is known that unreduced pollen is produced at times.

Discussion

In review, then, it should be noted that ways have been found to combine the fragrance of the diploid *Fragaria vesca* with the other good qualities of the cultivated octaploid strawberry. A needed type of tetraploid blueberry has been made to order. The origin of the Logan and Mammoth blackberries has been determined and many new Logan- and Mammoth-type berries originated. A tetraploid thornless blackberry is now available for producing hardy new thornless ones. The new 9-ploid Cascade blackberry, the finest in flavor of all known varieties, is now being grown in the Pacific Northwest. And the hardiness of a more northern tetraploid cranberry has been combined with the horticulturally better diploid varieties on the tetraploid level. There is still a wealth of wild forms not yet surveyed that will furnish the superior genes for the production of much finer fruits.

In this summary of the polyploid condition of fruits it becomes evident that, in many of them, polyploids are much superior to diploids and have already replaced the diploids wholly or in part, occasionally in nature and often in cultivation. The advantages of cultivated polyploids are evident. Octaploid strawberries are many times larger and more productive than the diploids. Tetraploid and hexaploid blueberries are larger berried than the diploids. Most of our cultivated blackberry varieties are tetraploids, selected from the wild for their size, self-fertility, productiveness, and flavor. Fruit of tetraploid grapes, apples, and pears are much larger than the diploid forms. Self-sterility of the diploid in some instances at least is replaced by self-fertility in the polyploid. The vigor of many polyploid plants is an expression of better adaptation to their present environment, as, for example, greater drought- and heat-resistance, better utilization of soil fertility, or deeper root system of the octaploid strawberries, as compared with the diploid forms. The tree of triploid apples is generally more vigorous and the branching stronger than that of the diploids.

There is, at present, some objection on the part of the consuming public to these larger fruits produced on biologically more efficient plants. The greatest complaint is that they lack the flavor of the smaller, old-fashioned sorts, most of which we now know were diploids. This is not the fault of the polyploid condition; it goes back to the ancestral material used. For example, let us keep in mind that the genes of the diploid *Fragaria vesca*, probably the most highly flavored of the wild species, did not directly enter into the makeup of the octaploid commercial strawberries; this has now been accomplished by breeders. It is equally true that the first of the polyploid blueberries introduced into cultivation did not carry the fine flavor of some of the wild sorts. In the early years of blueberry breeding it was not possible to produce the proper combinations. With the newer techniques the necessary polyploids have been produced with a level of flavor satis-

factory to the taste of the most discriminating consumer. The new blueberry varieties now being introduced are evidence of what can be done in controlling this important fruit character.

The more we know of how polyploidy operates to produce new species and varieties, the better we shall be able to use polyploidy as a means of improving our fruits.

Polyploid induction is another tool to be used by breeders along with hybridization to obtain improvements desired. The effects most often obtained through polyploidy are broader, thicker leaves, larger flowers, larger fruits and fertility of hybrids not fertile as diploids. Other desirable qualities may also be obtained, but thus far cannot be predicted. Polyploidy in nature has been associated with hybridization. Hybridization followed by doubling the chromosome number has given us most of our fruits.

It has been suggested that plants with basic chromosome numbers of 10 and higher may be of polyploid derivation (22). If this be true, only the peach, apricot, sweet cherry, raspberry, and a few blackberry varieties are not of polyploid origin. The apple, pear, and quince are now considered polyploids derived from crosses of 8- with 9-chromosome forms, with subsequent doubling of the chromosome number. The apple, pear, and grape may all be thought of as ancient polyploids. It may not be an impossibility to construct other new fruits from intergeneric crosses rather than just interspecific ones.

We have learned just a little of the effect of polyploidy on our cultivated fruits; but that little is good and indicates the possibilities ahead. Also, we have learned more of the ways in which diploids can be transformed into tetraploids and of how even higher polyploids can be produced. Though progress may not seem to be so rapid with these slower developing woody plants as with annual crops, very significant and important developments are being made.

In this very brief review of polyploidy in relation to fruit improvement, the viewpoint has been that of a builder surveying the possibilities in his material and the usefulness of his tools. The pile of material is enormous. There seem to be no unsurmountable barriers to the use of any of the material. Many tools are now available to fashion this material so that he can build exactly as he wishes. The only limits are his blueprint, his time, and his industry.

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